

# Design and Development of Bluetooth Enabled Mini Homogenizer for Laboratory Applications

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**Abstract**—This paper presents the design and development of a mini homogenizer suitable for laboratory-scale applications. The device replicates the quality of industrial homogenizers in a compact, cost-effective, and portable format. It integrates a DC gear motor, Arduino UNO, Bluetooth HC-05 module, LCD display, and safety alerts. The homogenizer enables precise speed control, wireless operation, and real-time monitoring, proving effective in pharmaceutical and biotechnological processes such as emulsification, nanosuspension preparation, and protein extraction. The proposed system provides a low-cost solution to laboratory-scale homogenization with improved safety, efficiency, and ease of use.

**Index Terms**—Biotechnology, DC Gear Motor, Homogenization, Mini Homogenizer, Particle Size Reduction, Pharmaceutical Applications

## I. INTRODUCTION

Homogenizers have long been utilized in the pharmaceutical industry, particularly for emulsification. However, in recent years, their applications have expanded significantly. They are now being increasingly employed in the production of advanced pharmaceutical systems such as liposomes, nanosuspensions, solid-lipid nanoparticles, tablet coating dispersions, micro-encapsulation, and in the disruption of cells for the extraction of therapeutic proteins from cell cultures.

The term "homogenize" refers to the process of forcing or promoting the coalescence of particles. Homogenization is specifically designed to achieve a uniform particle size within a substance. The main objective of this process is to apply fluid force to break down larger fragments or particles within fluids into smaller, more stable dimensions, resulting in a consistent dispersion that is suitable for further processing or production.

Homogenization is particularly important in the pharmaceutical and biotechnological fields, where the uniformity of particle size and stable dispersions are essential for various applications. Mixing, such as emulsification, is common practice in homogenizers, but these devices have recently received attention for their potential usage in novel drug delivery systems, including liposomes, nanosuspensions, and solid-lipid nanoparticles. Similar to tablet coating and micro-encapsulation, homogenizers can also be used to disrupt cells, allowing for the extraction of therapeutic proteins.

The report will summarize the development of the device, the objectives and functionality of the device, and the applications and benefits related to the likely use of mini homogenizers.

Among the basic operations that enable the development and manufacture of a variety of products in many industries, from pharmaceuticals to biotechnology, homogenization holds a highly important place. In short, the homogenization process is applied to achieve identical particle size and stable dispersion. Stable dispersion and uniform particle size are of major importance for ensuring the quality and effectiveness and safety of the product. Traditionally, homogenizers have been extensively utilized for emulsification, a process that plays an essential role in the production of creams, lotions, and suspensions. However, applications of homogenizers have risen sharply recently due to increased demand for sophisticated drug delivery systems

### 1.1 Homogenizers in Pharmaceutical Research

Manufacturing complicated formulations in the pharmaceutical industry has gained more complexity, and thus there is an increased need for effective homogenization techniques. Among the important formulations, those relevant for drug delivery systems in modern times are liposomes, nanosuspensions, and

solid-lipid nanoparticles. Liposomes are spherical vesicles with the drugs entrapped within a bilayer of lipids. These vesicles allow controlled release and targeted delivery of pharmaceuticals; they can be one way to significantly enhance therapeutic effect while reducing the side effects. Homogenization of the liposomes must be efficient in order to ensure homogeneous particle sizing and stability, with maximum performance being attained. Another innovative approach to enhance drug solubility and bioavailability in particular for those compounds that are poorly soluble is through nanosuspensions. The size reduction of the particles of drugs up to the nanometer scale affects its surface area allowing for a better dissolution leading up to the therapeutic effect. Advanced homogenization techniques have to be used as well for this nanoscale formulation because it has to reach the optimum particle size distribution without affecting the suspension stability. The other similar one is solid-lipid nanoparticles, which combines solid lipids with surfactants to produce an adaptable drug delivery system. These nanoparticles enhance the bioavailability of poorly soluble drugs and also offer controlled release properties. In the production of solid-lipid nanoparticles, emulsification and homogenization of lipid matrices take place, where uniformity in particle size is required to obtain uniform drug release profiles. In conclusion, the importance of homogenization in the pharmaceutical industry cannot be overstated since it relates directly to the quality and performance of these advanced formulations.

### 1.2 The Role of Homogenization in Biotechnology

There is much more to the role of homogenization than in pharmaceutical formulation. In biotechnology, one of the most critical processes related to the production of biopharmaceuticals is the extraction of therapeutic proteins from cultured cells; yield and purity of these proteins are the words. High-potency homogenizers utilize cell disruption and allow researchers the accessibility to isolate valuable proteins in biologics and advanced therapeutics research. With the efficient controlled breaking open of cells, intracellular components are thus extracted without causing significant destruction to sensitive biomolecules. Such capability is vital to the manufacture of therapeutic proteins of high quality that abide very stringent regulatory standards. In addition, homogenization also

enhances other bioprocesses; these include vaccine formulation and cell culture preparation. For instance, in vaccine production, homogenizers help to create stable emulsions that augment the delivery of antigens. This is crucial in the immunogenicity and effectiveness of vaccines. Similarly, the process of cell culture requires homogenization to ensure an even supply of nutrients that will enhance cell growth, which is important for the production of biopharmaceuticals

### 1.3 Need for Miniaturized Homogenizers

In such industries wherein homogenization appears so obviously crucial, the requirement for more compact and versatile equipment still arises within areas of research and development. Industrial homogenizers work just fine within several applications of large-scale production but not very well in a laboratory environment where the majority of the time small batches call for extreme precision. In this setting, therefore, miniaturized homogenizers prove increasingly important. These devices provide excellent quality homogenization in compact and user-friendly forms, making them a suitable choice for the mostly minimal available lab space while still being efficient.

Development of a mini homogenizer offers considerable advantages over the counterpart large-size versions. This allows working with small quantities of expensive or rare materials, decreasing waste, and consequently lowering the associated costs. Its utility lies especially in the early stages of drug development and experimental research where bulk production is out of the question. A mini homogenizer can also improve the reproducibility of experiments since it is possible to adjust to uniform operating conditions in carrying out numerous experiments. The portability of such an equipment allows for usage in a variety of settings-from academic laboratory settings to pharmaceutical research facilities.

Furthermore, mini homogenizers can be developed with certain capabilities suitable for the purpose of researchers working on a project, like adjustable speed settings and various homogenization modes that are compatible with different sample types. Within these flexibility and adaptability features, mini homogenizers may fit a wide array of applications, starting from basic research to advanced formulation development.

#### 1.4 Project Focus and Significance

The present project report deals with the design and fabrication of a mini homogenizer that can cater to stringent demands at a laboratory scale. The mini homogenizer would give quality in terms of size reduction equal to that achievable in large industrial homogenizers but in a compact and efficient format. A number of technical considerations involve motor selection, rotor-stator design, and material compatibility, with considerations to be addressed during development for optimal performance and longevity. It will also address the possible applications of the mini homogenizer in pharmaceutical and biotechnological research. This homogenizer provides easy and efficient realization of homogenization and can accelerate innovation, allowing superior experimental outcome in different applications. With this, the growing demand for advanced drug delivery systems and biopharmaceuticals will likely give the mini homogenizer a cardinal position in this aspect.

The mini homogenizer is therefore an innovation in the technology of homogenization, which bridges industrial-scale production and laboratory research. The different parts of this report that include its design, construction, and evaluation elaborate on versatility and crucial functions in producing breakthroughs in pharmaceutical and biotechnological researches. In response to increasing demand for a practical, compact, and efficient homogenization solution, this project is in pursuit of continuous innovation and development of high-quality pharmaceutical products and biotherapeutic

#### II. OBJECTIVE

The main objective of this project was to design and develop a mini homogenizer capable of managing homogenization at the laboratory scale, showing attractiveness in terms of productivity, portability, and effectiveness. This innovative device was looking to replicate the particle size-reducing and dispersion qualities in high-quality traditional large-scale industrialized homogenizers, while providing the advantages of compact, user-friendly format suitable to research and development environments. The mini homogenizer is designed to meet these requirements because of the frequent manipulation of limited amounts of samples and the need to completely control

the conditions of experiments. The mini homogenizer is small-sized, which will give researchers the ease of transportation and fitment in most laboratory environments. Therefore, it is an essential tool to be provided to the researcher, which he needs for the flexibility and convenience given by the experimental workflows. The mini homogenizer allows for effective and efficient processes of homogenization, which may be applied in enhancing quality and reproducibility of experimental results in pharmaceuticals, biotechnology, and materials science among others. It allows scientists to carry out small batch experiments with high accuracy, meaning better results with drug formulation and protein extraction among others. The project also takes into consideration the fact that there exists increased demand for advanced drug delivery systems and biopharmaceutical products requiring uniformly sized particles and stable dispersions. A device that may fulfil these requirements would significantly contribute to innovative and developments of high-quality pharmaceutical formulations and biotherapeutics.

#### III. REVIEW OF LITERATURE

[1] Homogenization technology has been shown to be an efficient and easy method of size reduction to increase solubility and bioavailability, stability of drug carriers. This article gives an overview of the process attributes affecting the homogenization process, the patenting of homogeniser types, design, the geometry of valves and nozzles and its role in drug delivery.

High-pressure homogenization (HPH) is one of the most important comminutions, mixing, and stabilizing technologies applied to pharmaceutical solids and nanoparticles. The technique has matured with nanotechnology advancement as it made possible the engineering of particles and increasing process capacity and efficiency. Fluid dynamics research has shaped innovative designs for high-pressure homogenizers. HPH is fairly versatile and easily scaled-up to prepare numerous types of lipid-based nano systems like nanoemulsions, SLNs, NLCs, nanocrystals, and polymeric nanoparticles. An overview of the processing attributes of HPH would be helpful for a chapter in the development of nanoparticles with desirable pharmaceutical attributes. Understanding fluid dynamics and processing

attributes of HPH would help develop nanoparticles with desirable pharmaceutical properties.

[2] Actual and theoretical aspects relevant when trying to prepare by ultrasonication very small nanoemulsions with very high stability are presented and discussed. The droplet size evolution during sonication can be described by a monoexponentially function of the sonication time, the characteristic time scale depending essentially on the applied power. Thus, for the first time, a master curve can be seen, which is strictly unique by plotting mean diameter size evolution against sonication energy. We then demonstrate that Ostwald ripening remains the dominating destabilization mechanism whereas coalescence can easily be avoided because of the nanometric size of the droplets. Incorporation of "trapped species" into the interior of droplets actually helps to counteract Ostwald ripening: the concept can be further transferred to the membrane compartment. We finally clarify that nanoemulsions are not thermodynamically stable systems, even in the case where their composition lies very close to the demising line of a thermodynamically stable microemulsion domain. However, as exemplified in the present work, nano emulsion systems can present very long-term kinetic stability.

[3] Described is a reliable high-pressure laboratory homogenizer for the small-scale production of emulsions with very reproducible droplet-size distribution. One characteristic feature of the design of this 'jet homogenizer' is that it possesses two different chambers holding the oil phase and the aqueous phase. Thus, as a rule, there is no need to premix before homogenization of the components - and of course, all the attendant difficulties of air entrainment are avoided. Performance characteristics of the jet homogenizer were demonstrated with data on the effect of homogenization pressure and equipment dimensions on the droplet size of n-tetradecane-in-water emulsions stabilized by sodium caseinate.

[4] The combination of homogenization with the experimental design, in turn, represents an efficient and straightforward approach to formulating and optimizing resistant starch type 3 nanoparticles (RS3NPs). Such a combination makes it possible to speedily scan multiple interacting factors and their interactions, making formulation parameters fine-

tuneable with very much greater precision and efficiency, underpinning nanoparticle properties.

Advanced analytical techniques were employed to characterise the RS3NPs in detail, which were produced through this method. Dynamic Light Scattering, DLS, was used for particle size distribution and zeta potential. It yields information about how stable the nanoparticles could be in suspension. The surface morphology and structural features of the nanoparticles could be visualised down to the micro- and nano scale by Scanning Electron Microscopy, SEM and resolution. The crystalline nature of the material was studied using X-ray diffraction analysis. For thermal characterization and study of transitions of the nanomaterials, Differential Scanning Calorimetry was utilized. Finally, FTIR spectroscopy was utilized to determine chemical composition and identify functional groups so that, with the molecular interactions in mind, it can give insight into any possible modification occurring during the process of homogenization.

The characterizations obtained showed that the pressure for homogenization had a considerable influence on the physicochemical characteristics of the resulting RS3NPs. It was indicated that higher pressures in the homogenization process led to notable particle size changes, surface morphology, and even crystallinity. These factors support the necessity of optimizing the homogenization process in such a way that the nanoparticles will meet the required specifications for their final application.

In addition, the RS3NPs showed some attractive functional properties. They showed an appreciably low in vitro starch digestibility rate, which is of prime interest in the development of resistant starch-based products intended to impact human health by leveraging benefits from products that provide enhanced glycaemic control and digestive health. The RS3NPs also showed high adsorption capabilities, which suggests their potential as efficient delivery vehicles for bioactive compounds or carriers of therapeutic agents. Another aspect is the long-term stability of the nanoparticles, which suggests that they can be employed in many industrial and pharmaceutical applications.

Overall, homogenization along with the experimental box-Behnken design provides an all-potent and efficient methodology for optimization in RS3NPs production. The full characterization by DLS, SEM,

XRD, DSC, and FTIR established how significant the homogenization pressure was in the characteristics of the nanoparticles and indicated possible use in functional food products and drug delivery systems.

[5] Emulsions have various application in industry and daily life. In the pharmaceuticals, the lipophilic active ingredients are usually formulated in the disperse phase of oil-in-water emulsions. Milk, butter and margarine are examples of emulsions in daily life. In the metal processing emulsions are used under the form of coolants. Emulsions can be produced with different systems. In the following, the process of high-pressure homogenization is briefly compared to other common mechanical emulsification systems. To simplify the choice of an emulsification system, the influence of the most important parameters of the emulsion formulation on the resulting mean droplet diameter in the most prevalent continuous emulsification systems is outlined. Subsequently, the most common high-pressure homogenization systems.

[6] Nowadays, BLDC motors are favoured due to their high efficiency, durability, and smooth torque provision with low maintenance compared to traditional brushed motors. Research during the late 20th century focused on the benefits emphasized by the BLDC motors, which state that they have higher power density and improved efficiency over AC and brushed DC motors. Among the very first articles on motor control, several attempts were devoted to using Hall effect sensors to determine the rotor position, which is then enabled through electronic commutation that allows the motor to operate. As sensorless methods of control gained widespread acceptance, largely due to the decreased cost and increased reliability, a myriad of new ways to estimate the position without physical sensors were devised. This is most notable through the means of the back-EMF detection - which was a very significant development in BLDC motor control.

The major trends and approaches that have been explored include several strategies for controlling BLDC motors, including PID controllers. PID controllers are quite popular and fairly simple to implement and tune but cannot handle system nonlinearities and variation

ions well. Therefore, the control techniques need to be more advanced. More adaptive solutions came with

techniques such as fuzzy logic control and model predictive control, but these added increased computational requirements, making them less feasible in cost-sensitive applications. In recent times, control strategies like field-oriented control or DTC have been successfully applied to BLDC motors, providing better dynamic responses and even more precise torque control. Although these techniques are computationally demanding, they have significantly enhanced the accuracy and performance of the BLDC motor at the industrial level, especially in high-speed and high-performance areas.

The work of Lucas and Tchebycheff (2020) falls within this emerging scope of research since the control techniques were meant to be synchronized with sensor less technology and real-time torque regulation. Their work is reflective of a larger trend of higher reliability and performance in BLDC motors, particularly in areas of industry that require accuracy as well as durability. These motors are increasingly omnipresent in industries including automotive and aerospace as well as manufacturing. The powertrain efficiency in the electric vehicle has been significantly improved due to the use of BLDC motors. Similarly, in industrial robotics, preference is being shown for compact size, high-torque, and long service life provided by BLDC motors.

However, one of the major challenges in the control of the BLDC motor is maintaining the precision of the sensorless operations. Sometimes, the estimation of the rotor position without the sensors leads to a considerable amount of torque ripple and efficiency reduction, mainly at low speeds. The situation is addressed by Lucas and Tchebycheff (2020) with an advanced control strategy meant to solve the drawbacks of typical sensorless control approaches. Their contribution is significant in pushing the boundaries of better performance in industrial conditions for BLDC motors. The efforts in this area are going to be focused in the future to refine sensorless control methods, advanced integration of algorithms, and artificial intelligence that could enhance the real-time performance of the motor in industrial applications.

Thus, in a very short period of time, immense contributions have been made in the control techniques of BLDC motors and thus improved their application in industrial environments. Work by Lucas and Tchebycheff represents an important contribution

to this field in the satisfaction of challenges and laying groundwork for future innovations.

[7] An article by Kim et al. in 2018, titled "High-speed motor technologies and their applications in the biomedical field" has placed particular emphasis on the developments pursued in high-speed motor technologies and significant contributions in the biomedical application area. To appreciate the developments that have eventually led up to this study, a review of the literature existing about the development of high-speed motor technologies as well as their evolution and increasing importance for biomedical engineering would be in order.

These include brushless DC and permanent magnet synchronous motors that have been among the most studied in the last two decades or so for their efficiency, precision, and compact sizes. Indeed, these motors have evolved in design and control strategies in the last two decades as well as become increasingly essential for various industries. Research dates back to the 1990s regarding the study of high-speed motors in areas such as aerospace, automotive, and industrial automation. These motors find great demand due to the possibility to operate at high rotary speed with little friction and minimum heat loss. They are used in any field where the values precision as well as reliability play an important role.

In the recent decades, these technologies have also found increasing use in the biomedicine field. The application of biomedical devices, in the form of surgical instruments, dental equipment, and prosthetic appliances, requires motors with high performance and accuracy in a small package size. With advancements in medical technology, the practice of surgery became more minimally invasive, and an increasing restriction on the location of all the medical instruments or devices inside the body mandated a requirement for miniature-sized, efficient, and high-speed motors. High-speed motors used in such devices assure more precise precision during surgery and high speed facilitates fast medical procedures.

For high-speed motors, study conducted in early 2000 reviewed the scenario of using such motors in the surgical instruments such as drills and bone saws that demand both powers along with precision. This period focused on enhancing the rotational speed of these motors without compromising control, otherwise leading to surgical complications. In this context,

control strategies of these motors, specifically sensorless control and FOC, were gaining attention as significant research areas. The techniques ensured that high-speed motors were still applicable for the precision needed in demanding applications at these speeds, thus addressing the core challenge: balancing speed against control.

Some examples of the application of high-speed motors include biomedical imaging instruments, such as MRI scanners and diagnostic equipment. These motors improve the medical imaging operations' high-quality speed to achieve higher accuracy for diagnoses. High-speed permanent magnet motors applied systems requiring fast, reliable mechanical movement have been accounted to a long period of effectiveness in diagnostic tools.

Moreover, the increasing trend of robotics in surgery and rehabilitation has increased the demand for high-speed motor technologies. In surgery, high-speed motors are increasingly desired not only for their precision but also for their speed because they have to bring control over delicate performances. Research done between the mid-2010s regarding the employment of BLDC motors in robotic arms stated that they require the speed and precision capabilities for successful interventions in minimally invasive surgeries. High speed motors in rehabilitation robotics will enable natural and responsive movements towards helping patients recover with prosthetics or robotic exoskeletons under precise control.

Kim et al. (2018) continues in this line of work by discussing the latest innovations in motor technologies as well as how these innovations are increasingly being used in cutting-edge biomedical devices. Thus, they urge support for continued advance in materials science and motor design with a high development rate to sustain miniaturization of motors and seek enhanced efficiency of motors for biomedical applications. When more accurate, higher-speed motors are needed by later biomedical technology, increased demands will be placed on further research and development.

[8] Article by Goodenough and Kim (2010), "Challenges for Rechargeable Li Batteries" discusses the technical and scientific hurdles in finding advancements with lithium-ion (Li-ion) battery technology that is critical to electric vehicles, renewable energy storage, and consumer electronics applications. Since the Li-ion batteries came into the

commercial market during the 1990s, there has been extensive use of Li-ion batteries on account of their high energy density and long cycle life. However, the endeavour for additional capacity as well as better safety demands a set of challenges in this field-safety issue, material sustainability, and low energy density. Researchers initially concentrated on optimizing materials-including cobalt-based cathodes and graphite anodes-making the battery efficient. As time passed, NCM cathode and silicon anode based innovative materials have not only hindered further efficiency but also subjected problems such as degradation of capacity and structural instability.

Recent development in the area has concerned itself with improvements and safety of electrolyte systems from the problems of lithium metal anodes, such as their tendency to form dendrites that may have a way to short circuit. Other researchers are also involved in the solid-state electrolytes as alternatives to liquid electrolytes. However, solid-state electrolytes present problems with respect to ionic conductivity and interface stability. Sustainability is another critical issue, through recycling systems and substituting materials to reduce reliance on scarce materials, such as cobalt and lithium. These challenges become a backdrop under which the achievement of Goodenough and Kim underlines, outlining the requests for innovation in materials and designs to balance toward energy density, safety, and sustainability with Li-ion battery technologies.

[9] The article of Park et al. "Lithium-ion Battery Technologies: Innovations and Improvements for Portable Applications" discusses some of the latest developments and recent innovations that have been taking place in lithium-ion (Li-ion) battery technology, specifically focusing on improvements for portable electronics. Li-ion batteries dominate the portable device market with their high energy density, long cycle life, and lightweight properties. However, due to the demand for energy densification, compact, and durability of batteries, some notable research activities have been done to enhance the performance of the battery and overcome restrictions associated with a compromise in the capacity, safety, and environment.

Many recent reviews focus on the development of li-ion batteries and the innovation that is pursued in electrode materials such as silicon anodes and high-

nickel cathodes to maximize the energy density while minimizing weight and volume. Research is also focused on the enhancement of the electrolyte systems in the electrolyte battery with an eye on the risk factors regarding thermal runaway and flammability. Additionally, the intense focus remains on the solid-state batteries as well as even more advanced designs for the battery as they not only enhance performance but also have safety features integrated into the portable applications. It is according to Park et al. (2019) that these

advancements will be seen in next-generation portable electronics with higher efficiency and faster charging rates and increased battery life as some of the driving demands consumers would insist on.

[10] Smith and West 2016: This provides an exhaustive review of the design and optimization of the homogenizing heads specifically designed for laboratory use. Their research would be aimed at the development of efficient homogenizing systems that give high, consistent particle size reduction and uniformity of samples, very crucial in any scientific experiment. Most past research in the area has emphasized the challenges of scaling industrial techniques for homogenization to the laboratory level, mainly because of demands like precision, simplicity, and cost-effectiveness on a small scale.

The development of new fluid dynamics as well as material selection and usage are emphasized by the authors to enhance efficiency and endurance of the homogenizing heads. Design improvements about optimized flow patterns together with reduced wear ensure better performance as well as durability. Such types of research work build on or make shared knowledge about designs for laboratory equipment, where innovations in material science and mechanical engineering occur in a broad common sense.

[11] Patel et al. discuss in their 2020 study, the optimization of rotor-stator geometries for the enhancement of fluid homogenization efficiency in such fields as pharmaceutical, food processing, and chemical engineering industries. Fluid homogenization is considered crucial since it ensures there are no uniform particle sizes distribution in mixtures but rather a homogeneous mixture, which would ensure quality and performance of the products at the end. The main concern of the research is to

investigate several designs of rotors and stators concerning geometric variation and its effects on fluid dynamics as well as the efficiency of the homogenization process.

Rotor-stator systems are among the most crucial homogenizers mechanisms that develop friction forces via the high-speed revolution of the rotor with concomitant flow confinement and guiding through the stator in breaking down the particles to attain homogenous mixing. This paper mainly focuses on how geometrical alteration to the rotor-stator system, like diameter changes of the rotor, size of gap between the rotor and stator, and design of blades will be adopted to optimize the homogenization process. While previous studies indicated that homogenization efficiency was largely influenced by the rotor and stator interaction, Patel et al. seem to stress how optimal geometric adjustments improve the process better.

The researchers study these geometric variables for potential impacts on fluid flow, shear stress distribution, and overall mixing efficiency by using a combination of CFD simulations and experimental trials. The CFD simulations allow carrying out detailed analysis of fluid behaviour in various geometrical conditions, thereby providing an insight into optimized configurations that should be looked for better homogenization. For instance, smaller gaps between the rotor and the stator raise the shear forces; therefore, the particle size distribution becomes finer, but energy consumption rises. Conversely, a balance between energy efficiency and quality of homogenization can be achieved if the design of rotor blades is adapted.

Thus, in a great way, optimal geometries of the rotor-stator may really enhance fluid homogenization processes, as the Patel et al. study suggests. After identifying ideal configurations, a path toward developing more energy-efficient and effective homogenizers emerges, which is critical for industries requiring constant product quality and process optimization. Their work is in the constant development of homogenization technology and their design solutions can be useful for many industrial applications since they assure great control over fluid properties and particle dispersion.

[12] Tayeb and Kholidy (2020) comprehensively review the IoT mobile applications designed to operate

smart devices. As IoT technologies have experienced rapid growth, so have mobile apps turned out to be an essential interface in managing and operating a diverse range of smart devices, from home automation systems to industrial machinery. The review focuses on the functionalities and features that qualify IoT mobile apps as part of the backbone for managing and controlling connected devices in various domains, such as smart homes, healthcare, manufacturing, and transportation.

It then analyses the types of communication protocols used by IoT mobile apps, including Bluetooth, Wi-Fi, Zigbee, and cellular networks, which may help establish connectivity between the smartphones and the smart device. This communication technology allows users to get access to and interact with devices of IoT over the Internet, check the status of these devices from a remote location, switch devices off or on, adjust settings, or automate certain operations. Tayeb and Kholidy stress the need for dependable and seamless communication to ensure proper functionality of the IoT. Advances in cloud computing and edge computing have further elevated the performance of IoT mobile apps through their capacity to process data at faster speeds and integrating them with large IoT networks.

Despite the benefits offered by IoT mobile apps, the review points out some challenges brought along in the development and deployment process. Key among them is security, given that many IoT devices are quite vulnerable to cyber-attacks. The type of mobile applications that run the devices should feature some of the best encryption protocols and robust security measures for other forms of related sensitive data. The authors show a discussion on how security vulnerability in IoT applications can lead to potential breaches in both privacy and safety, thus making security the major concern when developing the app. Connectivity issues also pose a big challenge because these have relied on stable network connections with no interruptions to work effectively. Controlling devices may be delayed or even disrupted from performing what they are supposed to do in an environment where connectivity is low.

Tayeb and Kholidy also echo the fact that user-friendly interfaces are needed since IoT systems are highly complex functionalities that confuse most of the users. One of the essential aspects of mobile applications is the design of intuitive and simple

interfaces that would ensure an enjoyable user experience. Another topic they cover is how IoT mobile applications have become much more flexible and scalable. They are now capable of handling ever more increasing numbers of devices as well as complex operations. This flexibility is crucial because the number of IoT devices is ever increasing exponentially, and even more industries are embracing IoT solutions.

This review by Tayeb and Kholidy emphasizes the central role of IoT mobile apps in smart devices but underlines the key challenges developers face regarding security, connectivity, and user experience. Their research underscores the need for continued innovation to address these challenges and make IoT mobile applications more functional, safe, and accessible

#### IV. DESCRIPTION AND EQUIPMENTS

##### 4.1 Dc Gear Motor

###### General Description

The relationship between torque vs speed and current is linear as shown left; as the load on a motor increase, Speed will decrease. The graph pictured here represents the characteristics of a typical motor. As long as the motor is used in the area of high efficiency (as represented by the shaded area) long life and good performance can be expected. However, using the motor outside this range will result in high temperature rises and deterioration of motor parts. A motor's basic rating point is slightly lower than its maximum efficiency point. Load torque can be determined by measuring the current drawn when the motor is attached to a machine whose actual load value is known.

###### Product Description

Geared dc motors can be defined as a n extension of dc motors A geared DC Motor has a gear assembly attached to the motor. The speed of motor is counted in terms of rotations of the shaft per minute and is termed as RPM. The gear assembly helps in increasing the torque and reducing the speed. Using the correct combination of gears in a gear motor, its speed can be reduced to any desirable figure. This concept where gears reduce the speed of the vehicle but increase its torque is known as gear reduction. A DC motor can be used at a voltage lower than the rated voltage. But,

below 1000 rpm, the speed becomes unstable, and the motor will not run smoothly.

##### 4.2 Power Supply

###### Understanding 7805 IC Voltage Regulator

A regulated power supply is very much essential for several electronic devices due to the semiconductor material employed in them have a fixed rate of current as well as voltage. The device may get damaged if there is any deviation from the fixed rate. The AC power supply gets converted into constant DC by this circuit. By the help of a voltage regulator DC, unregulated output will be fixed to a constant voltage. The circuit is made up of linear voltage regulator 7805 along with capacitors and resistors with bridge rectifier made up from diodes. From giving an unchanging voltage supply to building confident that output reaches uninterrupted to the appliance, the diodes along with capacitors handle elevated efficient signal conveyed.

###### Description:

As we have previously talked about that regulated power supply is a device that mechanized on DC voltages and also it can uphold its output accurately at a fixed voltage all the time although if there is a significant alteration in the DC input voltage.

ICs regulator is mainly used in the circuit to maintain the exact voltage which is followed by the power supply. A regulator is mainly employed with the capacitor connected in parallel to the input terminal and the output terminal of the IC regulator. For the checking of gigantic alterations in the input as well as in the output filter, capacitors are used. While the bypass capacitors are used to check the small period spikes on the input and output level. Bypass capacitors are mainly of small values that are used to bypass the small period pulses straightly into the Earth.

The working of the components coupled in the circuit above is revealed in the following table:

As we have made the whole circuit till now to be operated on the 5V DC supply, so we have to use an IC regulator for 5V DC. And the most generally used IC regulators get into the market for 5V DC regulation use is 7805. So, we are connecting the similar IC in the circuit as U1.

IC 7805 is a DC regulated IC of 5V. This IC is very flexible and is widely employed in all types of circuit

like a voltage regulator. It is a three terminal device and mainly called input, output and ground.

The pin explanation of the 7805 is described in the following table:

In the circuit diagram C2 as well as C3 are filter capacitor while bypass capacitors are the C1 and C4. The electrolytic polarized capacitors are employed for this purpose. For the purpose of filter capacitors normally 10mfd value of the capacitor used. And in these projects, we also used 100mfd value of the capacitor. While in all kinds of circuit the value of bypass capacitor is 0.1 mfd. And in generally unpolarized mainly disc capacitors employed for this purpose.

Currently we have the circuit for the 5V DC positive regulation and we are also familiar with the component values used in the circuit. In the table below we have mentioned the value in detail of all the components used in the circuit of 5V DC positive regulator

#### 4.3 Transformer (0-12v/1a)

##### General Description

It is a general-purpose chassis mounting mains transformer. Transformer has 240V primary windings and center tapped secondary winding. The transformer has flying colored insulated connecting leads (Approx 100 mm long). The Transformer act as step down transformer reducing AC - 240V to AC - 12V. Power supplies for all kinds of project & circuit boards. Step down 230 V AC to 12V with a maximum of 1Amp current. In AC circuits, AC voltage, current and waveform can be transformed with the help of Transformers. Transformer plays an important role in electronic equipment. AC and DC voltage in Power supply equipment are almost achieved by transformer's transformation and commutation

##### Product Description

A transformer is an electrical device that transfers electrical energy between two or more circuits through electromagnetic induction. Electromagnetic induction produces an electromotive force within a conductor which is exposed to time varying magnetic fields. Transformers are used to increase or decrease the alternating voltages in electric power applications. It is a step-down transformer in which the secondary winding is more than primary winding. Due to this winding, it can able to step down the voltage. A

Transformer changes electricity from high to low voltage or low to high voltage using two properties of electricity.

##### Features

- Output current: 1 A
- Supply voltage: 220-230V ac
- Output voltage: 12V ac
- Soft Iron Core
- 1Amp Current Drain

##### Applications

- DIY project Requiring In-Application High current drain.
- On chassis DC/AC converter.
- Designing a battery charger.
- Electronic applications.
- Step down applications (Power transmission).

#### 4.4 Arduino Uno

##### General Description

Arduino is an open-source project that created microcontroller-based kits for building digital devices and interactive objects that can sense and control physical devices. The project is based on microcontroller board designs, produced by several vendors, using various microcontrollers. These systems provide sets of digital and analog input/output (I/O) pins that can interface to various expansion boards (termed shields) and other circuits. The boards feature serial communication interfaces, including Universal Serial Bus (USB) on some models, for loading programs from personal computers. For programming the microcontrollers, the Arduino project provides an integrated development environment (IDE) based on a programming language named Processing, which also supports the languages C and C++.

##### Product Description

Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter. Arduino Uno has a number of facilities for communicating with a

computer, another Arduino board, or other microcontrollers.

Figure 1- Arduino Uno

Features:

- Microcontroller: ATmega328P
- Operating voltage: 5V
- Input voltage: 7-12V
- Flash memory: 32KB
- SRAM: 2KB
- EEPROM: 1KB

Applications

- Real time biometrics
- Robotic applications
- Academic applications

#### 4.5 16×2 LCD

General Description

LCD stands for liquid crystal display. They come in many sizes 8x1, 8x2, 10x2, 16x1, 16x2, 16x4, 20x2, 20x4, 24x2, 30x2, 32x2, 40x2 etc. Many multinational companies like Philips Hitachi Panasonic make their own special kind of LCD'S to be used in their products. All the LCD'S performs the same functions (display characters numbers special characters ASCII characters etc.). Their programming is also same and they all have same 14 pins (0-13) or 16 pins (0 to 15). Alphanumeric displays are used in a wide range of applications, including palmtop computers, word processors, photocopiers, point of sale terminals, medical instruments, cellular phones, etc.

Product Description

This is an LCD Display designed for E-blocks. It is a 16 character, 2-line alphanumeric LCD display connected to a single 9-way D-type connector. This allows the device to be connected to most E-Block I/O ports. The LCD display requires data in a serial format, which is detailed in the user guide below. The display also requires a 5V power supply. Please take care not to exceed 5V, as this will cause damage to the device. The 5V is best generated from the E-blocks Multi programmer or a 5V fixed regulated power supply. The 16 x 2 intelligent alphanumeric dot matrix displays are capable of displaying 224 different characters and symbols. A full list of the characters

and symbols is printed on pages 7/8 (note these symbols can vary between brand of LCD used). This booklet provides all the technical specifications for connecting the unit, which requires a single power supply (+5V).

Figure 2 - 16×2 LCD

Features

- Input voltage: 5V
- E-blocks compatible
- Low cost
- Compatible with most I/O ports in the E-block range
- Ease to develop programming code using Flow code icons

Applications

- Monitoring

#### 4.6 Bluetooth Hc05

Introduction

The HCOS Bluetooth Module can be used in a Master or Slave configuration, making it a great solution for wireless communication. You can use it simply for a serial port replacement to establish connection between MCU and GPS, PC to your embedded project. The HCOS Bluetooth Module has 6 pins Vee, GND, TX, RX, Key, and LED. It comes preprogrammed as a slave, so there is no need to connect the Key pin, unless you need it change it to Master Mode. The major difference between Master and Slave modes is that, in Slave mode the Bluetooth module cannot initiate a connection, it can however accept incoming connections.

After the connection is established the Bluetooth module can transmit and receive data regardless of the mode it is running in. If you are using a phone to connect to the Bluetooth module, you can simply use it in the Slave mode. The default data transmission rate is 9600kbps. The range for Bluetooth communication is usually 30m or less. The module has a factory set pin of "1234" which is used while pairing the module to a phone.

The HC-05 module can build a connection to other modules. E.g. a robot being a master and connecting to slave Bluetooth module. Or in slave mode to make a wireless bridge to a notebook.

Pin Configuration

- I. STATE: NC (NO CONNECTION).

- II. RX: TX OF MICROCONTROLLER.
- III. TX: RX OF MICROCONTROLLER.
- IV. GND: GROUND.
- V. VCC: +5V.
- VI. EN: NC (NO CONNECTION).

STATE” ‘Lull--

Rx---

Tx-•--

GND ""111--

V.VCC.,,,

VI.EN

Figure 3 – Bluetooth HC05

FEATURES:

Protocol: Bluetooth Specification v2.0+EDR

Frequency: 2.4GHz ISM band

Modulation: GFSK

Emission power: 4dBm, Class 2

Sensitivity: 84dBm at 0.1% BER

Speed: Asynchronous: 2.1 Mbps (Max)/ 160 kbps,

Synchronous: 1Mbps/1Mbps

Security: Authentication and encryption

Profiles: Bluetooth serial port profile (SPP)

Power supply: +3.3VDC 50mA

Working temperature: 20 ~ +75 Centigrade

Range: Up to 10cm

Advantages:

Good Range and High Data transfer speed.

Compact Size.

TTL Interface.

It comes with integrated antenna.

It operates at low power

Applicatons:

Computer and peripheral devices

GPS receiver

Industrial control

Microcontroller unit projects

Mouse, keyboard, joystick

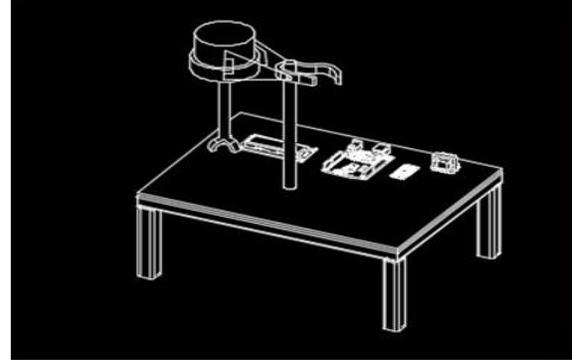


Fig. 1: Isometric View

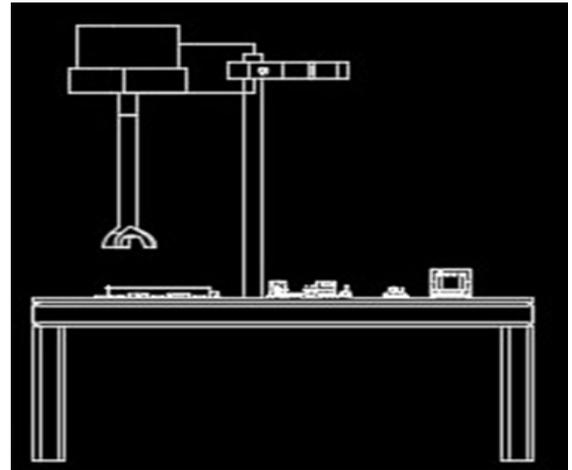


Fig. 2: Side View

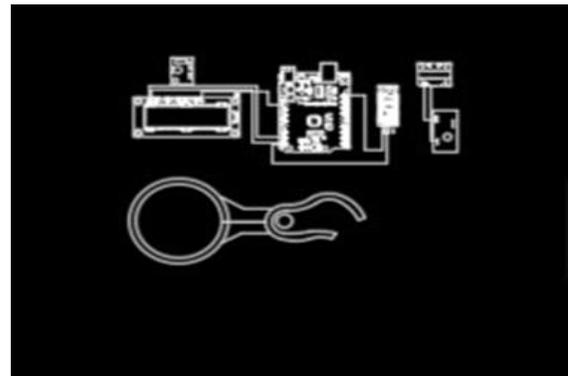


Fig. 3: Top View

## V. DESIGN OF THE EQUIPMENT

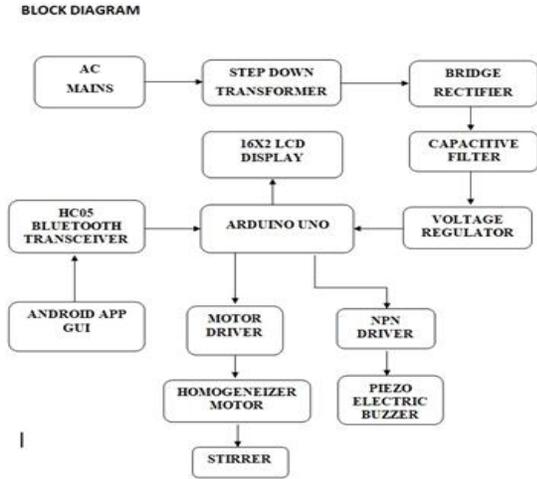


Fig. 4: Block Diagram

## VI. COST ESTIMATION

### Advantages:

**Remote Operability:** The integration of a Bluetooth module allows users to control the homogenizer through an Android app, offering the convenience of wireless operation. This feature reduces the need for constant physical presence, increasing operational flexibility and efficiency.

**Precise Speed Control:** The system provides adjustable speed settings (25%, 50%, 75%, and 100%), allowing users to customize the homogenization process as needed. This ensures better process control and consistent results, which are essential for applications requiring specific mixing conditions.

**Real-Time Monitoring:** The inclusion of a 16x2 LCD display enables users to monitor the motor's RPM in real-time. This feedback helps maintain desired operational parameters, ensuring consistent performance and reducing errors.

**Enhanced Safety Features:** A built-in alert mechanism that activates a long beep when the stirrer stops ensures that users are immediately aware of any change in operation. This improves user awareness and helps prevent unnoticed stoppages that could disrupt processes or lead to safety concerns.

**Ease of Use:** The system's user-friendly interface, operated via an Android app, simplifies the control process. Users can easily start, stop, or change speed settings without complicated manual controls, making

it accessible even to those with minimal technical experience.

**Compact and Portable Design:** The "Mini Homogenizer" is designed to be compact, making it easy to fit into various laboratory and workspace setups without taking up excessive space.

**Cost-Effective Solution:** By utilizing readily available components such as the Arduino microcontroller, TIP122 transistor, and a standard Bluetooth module, the system remains affordable without compromising functionality. This makes it an attractive option for small laboratories or budget-conscious facilities.

**Customizability and Expandability:** The system's design can be easily modified or expanded for additional features or upgrades, such as integrating more advanced sensors or connectivity options.

**Reduced User Fatigue:** The remote-control capability and automatic speed adjustments mean users do not need to remain at the machine continuously, reducing fatigue during long mixing operations.

**Versatile Applications:** The "Mini Homogenizer" can be used for a variety of applications, from laboratory research to small-scale production, due to its adjustable speed control and compact size.

These advantages make the "Mini Homogenizer" a modern, efficient, and practical solution that addresses the challenges of traditional homogenization systems while adding significant improvements in convenience, control, and safety

## VII. RESULTS AND DISCUSSION

The "Mini Homogenizer" project achieved its main goals of developing an efficient, user-friendly, and remotely controlled homogenization system. The prototype was successfully tested and demonstrated key functionalities, which are discussed below:

### VIII. RESULTS

**Wireless Control Achieved:** The Bluetooth module effectively established communication between the Android app and the Arduino microcontroller, allowing seamless transmission of commands. Users were able to start, stop, and adjust the speed settings remotely, confirming the system's responsiveness and reliability in wireless operation.

**Speed Control Performance:** The homogenizer demonstrated precise speed adjustments at the present

levels (25%, 50%, 75%, and 100%). The Arduino-controlled TIP122 transistor generated PWM pulses that modulated the motor speed accurately. Each speed setting showed consistent RPM outputs, validating the system's ability to maintain stable operation across different intensities.

**Real-Time RPM Display:** The 16x2 LCD display provided continuous feedback on the motor's RPM. This feature worked as intended, giving users real-time insight into the current operating state. This visibility allowed for quick verification and adjustments as needed.

**Safety Alerts:** The integrated buzzer successfully emitted a long beep when the stirrer stopped, serving as an effective alert mechanism. This ensured that users were immediately aware of any unexpected stoppages, enhancing operational safety.

**User Experience:** Testers found the system intuitive to use, with straightforward navigation through the Android app and simple monitoring of the LCD display. The remote-control function significantly improved user convenience, allowing operators to control the process from a distance and reducing the need for continuous manual adjustments.

## IX DISCUSSION

**Efficiency and Precision:** The use of PWM to control motor speed proved to be effective, offering smooth and precise speed transitions. This enhanced the consistency of the homogenization process, which is critical for both laboratory and small-scale industrial applications.

**Safety and Awareness:** The alert system provided by the buzzer added an essential safety feature, especially in unattended operations. This functionality can prevent operational oversights and potential damage caused by an unnoticed stop.

**Limitations:** While the project was successful, potential areas for improvement include integrating more advanced monitoring features such as temperature sensors or a graphical display for more comprehensive feedback. Additionally, enhancing the range and stability of the Bluetooth connection could improve operability in larger facilities.

**Future Enhancements:** Incorporating additional control options such as adjustable PWM modulation for finer speed tuning and expanding connectivity (e.g., Wi-Fi or IoT integration) would make the system

more versatile. Upgrading the user interface of the Android app for more detailed control and monitoring capabilities would also be beneficial.

## X. CONCLUSION

The "Mini Homogenizer" project successfully demonstrated a modern approach to homogenization by incorporating wireless control, precision speed adjustment, real-time monitoring, and safety features. The integration of a Bluetooth module and an Android app allowed for seamless remote operation, making the system highly user-friendly and efficient. The use of an Arduino-controlled TIP122 transistor ensured precise motor speed regulation via PWM pulses, providing consistent performance across different speed settings.

The real-time RPM display on a 16x2 LCD and the alert system, which triggered a long beep when the stirrer stopped, significantly enhanced the user experience by offering transparency and safety during operation. The compact, cost-effective design makes this system an ideal solution for laboratory and small-scale industrial applications.

Overall, the "Mini Homogenizer" effectively addresses the limitations of traditional homogenization systems by offering better control, flexibility, and user safety. Future enhancements, such as integrating more sensors, improving connectivity options, and expanding app functionalities, could further strengthen its capabilities and widen its application range. The project showcases how modern electronics and wireless technology can transform conventional processes into more advanced and efficient solutions.

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