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DESIGN AND FABRICATION OF A HAND–CRANKED TWO–ROLLER SUGARCANE PRESS

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Abstract: This paper presents the design and fabrication of a compact, hand–cranked two–roller sugarcane press developed through an integrated CAD–CAM–CNC workflow. The design was based on an experimentally determined torque requirement, achieved via a 4:1 spur gear reduction to amplify manual input for juice extraction. A complete digital manufacturing process was employed, including CAD modelling, NX CAM tool path generation, and CNC machining of key components such as rollers, gears, and frame plates. The fabricated prototype was successfully assembled and validated against the CAD model, demonstrating smooth roller rotation, stable gear meshing, and effective compressive action for small–scale juice extraction. The results highlight the feasibility of using modern digital design and manufacturing technologies for the development of low–cost mechanical devices intended for educational and demonstration purposes. Limitations of the current prototype include the use of POM plastic for structural components, the absence of an adjustable roller gap, and reliance on manual operation. Future improvements will focus on material upgrades, roller surface optimization, adjustable nip mechanisms, motorization, and performance testing to expand applicability beyond academic demonstration toward semi–industrial contexts.

Keywords: rolling, mechanism, prototype design, fabrication

INTRODUCTION

Sugarcane juice extraction is a process with both industrial and domestic significance, as it provides a low–cost and natural beverage widely consumed in many tropical countries [1–3]. Conventional sugarcane presses are often large–scale, electrically driven, and intended for industrial throughput [4–5]. While effective, these machines are costly, complex to maintain, and not always suitable for small enterprises, rural communities, or educational demonstration purposes. There exists a need for compact, low–cost, and manually operated alternatives that can be fabricated with modern tools while still providing adequate force transmission for juice extraction [6–8]

In parallel, the evolution of design and manufacturing technologies has made it possible to shorten product development cycles and improve reproducibility even for small–scale prototypes. The integration of computer–aided design (CAD), computer–aided manufacturing (CAM), and computer numerical control (CNC) machining allows for precise modelling, simulation, and fabrication of mechanical systems [9–15]. The development of a hand–cranked sugarcane press provides a meaningful case study for applying CAD/CAM/CNC in the design of a functional product. From a mechanical perspective, the device requires careful consideration of torque requirements, gear ratios, roller design, and structural integrity. Unlike conventional designs, which often prioritize mass production, the present work emphasizes feasibility, manufacturability, and educational demonstration. Specifically, the objective was to design a two–roller press that can be operated manually yet still deliver sufficient compressive force to extract juice at a controlled nip gap.

This study contributes in three main aspects. First, it demonstrates how an experimentally determined torque requirement can be translated into an effective gear–driven hand–crank mechanism. Second, it validates a complete digital manufacturing workflow using NX CAM for tool path generation and CNC machines for fabrication. Third, it provides practical assembly and performance insights that can inform future improvements, such as material upgrades, motorization, and hygiene considerations. In doing so, the work not only delivers a working prototype but also highlights the broader role of CAD–CAM–CNC integration in modern mechanical engineering education and prototyping.

MATERIALS AND METHODS

Geometric Modelling and Working Mechanism

Figure 1 presents the three–dimensional CAD model of the hand–cranked sugarcane press, with the principal components labelled. The model reveals the integration of four major subsystems: the hand crank, the gear transmission, the roller assembly, and the supporting frame.

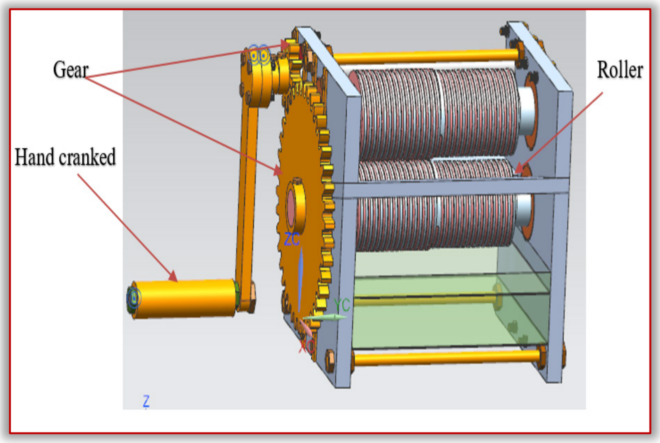

Figure 1. 3D CAD model of the hand–cranked two–roller sugarcane press

The hand crank functions as the input device, converting human effort into rotational motion. This motion is transmitted to a small spur gear, which engages a larger spur gear fixed on the first roller shaft. The 4:1 gear ratio increases the input torque while reducing rotational speed, thereby ensuring adequate force transmission to the rollers. Roller 1 is directly driven by the large gear, while Roller 2 counter–rotates due to direct contact with Roller 1, establishing synchronized rotation.

When sugarcane stalks are introduced into the roller nip gap (set at 0.8 mm), compressive forces are applied, causing juice extraction while fibrous residue is expelled. The frame and supports maintain structural rigidity and roller alignment, with bearings facilitating smooth motion under load.

The working principle can be summarized as: manual force applied at the crank is converted into amplified torque through the gear train, which drives the rollers in counter–rotation to achieve effective juice extraction. This figure not only demonstrates the mechanical feasibility of the design but also highlights the role of CAD in ensuring alignment, visualizing assembly, and validating torque transmission prior to fabrication.

Manufacture of Main Parts of the Mini Sugarcane Press Model

Figure 2 illustrates the CAM simulation of the side frame plate of the mini sugarcane press, generated in Siemens NX CAM. The simulation validates the milling tool paths prior to CNC machining. The operations primarily involve end milling processes for pocketing and contour cutting. Larger circular pockets are milled to reduce weight and accommodate roller shafts, while contour milling defines slots and external edges to ensure precise integration with the frame assembly. The colored tool trajectories indicate approach, cutting, and retract movements, confirming collision–free paths and efficient machining sequences. This CAM validation step ensures manufacturability, dimensional accuracy, and reliable CNC milling outcomes.

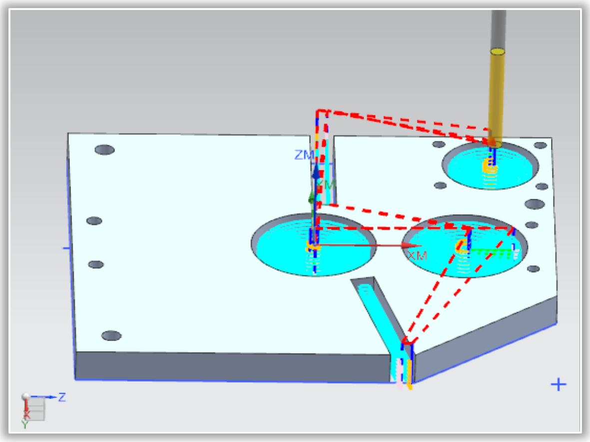

Figure 2. The CAM simulation process for machining one of the side plates

Figure 3. CNC milling of the side plate made from POM engineering plastic

Figure 3 shows the experimental CNC milling of the side plate made from POM engineering plastic. The work piece is securely clamped on the machine table, and end milling operations are used to generate the circular pockets and slots as programmed in NX CAM. The white plastic chips around the work area indicate successful material removal with good chip evacuation. The machined features, including circular recesses for roller shafts and structural slots, match the CAM simulation presented earlier.

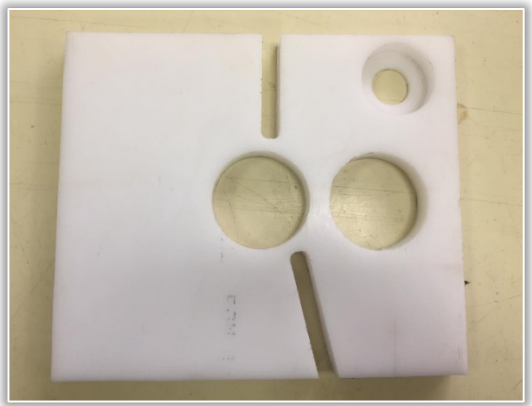

Figure 4. Finished Side Plate after CNC Milling

Figure 4 presents the completed side plate fabricated from POM engineering plastic after CNC end milling. The machined features include circular recesses for roller shafts, a smaller hole for fastening or alignment, and slots for frame integration. The dimensions and geometry correspond precisely with the CAD model and CAM simulation, confirming the accuracy of the digital–to–physical workflow.

Compared with the intermediate stage shown in Figure 3, the final part demonstrates smooth surface finish, proper edge definition, and dimensional precision suitable for subsequent assembly of the sugarcane press. This result validates the effectiveness of NX CAM programming and CNC machining in achieving design specifications with high fidelity.

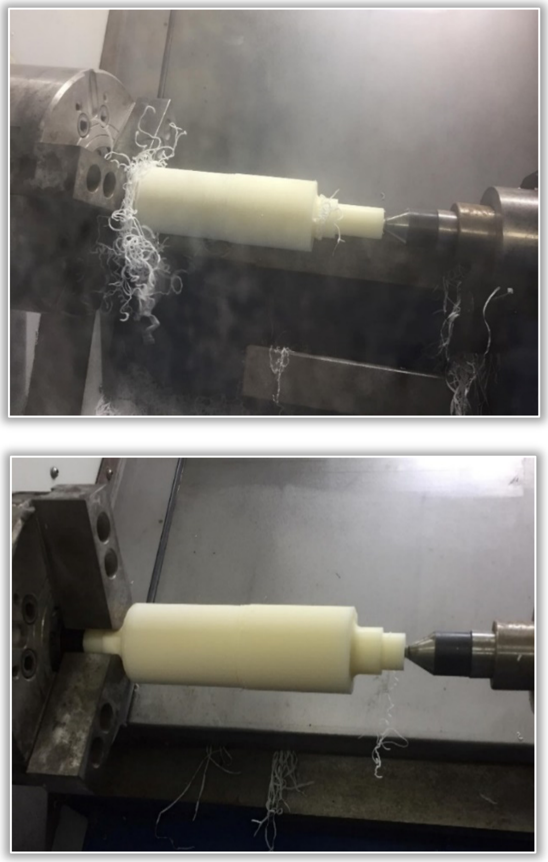

Figure 5. CNC Turning of the Roller Component

Figure 5 illustrates the manufacturing process of the roller using CNC turning operations. The roller blank, made from engineering plastic, is mounted between the chuck and the live centre to ensure accurate alignment and stability during machining. The left–hand image shows the rough turning stage, where excess material is removed to form the cylindrical body. The right–hand image shows the finishing stage, in which stepped features are generated at both ends to accommodate shaft connections, bearings, and gear attachments.

CNC turning provides high dimensional accuracy and surface quality, both of which are critical for roller functionality in juice extraction. The smooth cylindrical surface ensures effective compression of sugarcane stalks, while the stepped ends guarantee proper assembly within the frame and secure transmission of torque. This process validates the role of CNC turning in fabricating rotating elements of the mini sugarcane press with consistency and precision.

Figure 6. Finished Roller Components

Figure 6 presents the final pair of rollers produced through CNC turning. Each roller consists of a smooth cylindrical body and stepped ends designed for bearing mounting, gear attachment, and shaft alignment. The precise geometry achieved ensures correct meshing, stable rotation, and uniform compression of sugarcane stalks during operation. The consistent surface finish of the cylindrical section is critical for maintaining effective contact with the sugarcane and for achieving controlled juice extraction.

The two rollers are dimensionally identical to guarantee synchronized counter–rotation within the press. Their accurate manufacture validates the design approach, confirming that CAD/CAM modelling and CNC machining can successfully deliver functional components with the required tolerances and surface quality.

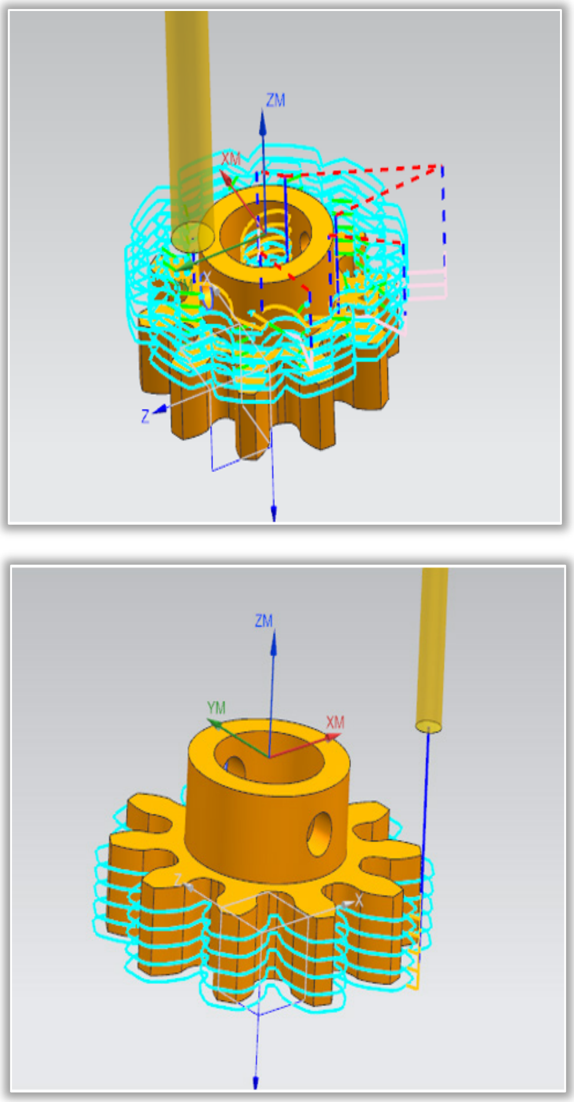

Figure 7. The CAM simulation of the spur gear machining process

Figure 7 depicts the CAM tool path simulation for fabricating a spur gear used in the transmission system of the mini sugarcane press. The simulation, carried out in Siemens NX CAM, demonstrates the use of end milling operations to generate both the gear teeth profile and the central bore. The left–hand image highlights the machining of the central bore and surrounding surfaces, where helical tool paths ensure uniform material removal and dimensional precision. The right–hand image focuses on the gear teeth formation, showing contour tool paths that trace the gear profile layer by layer to achieve the required geometry. By validating the tool paths prior to machining, the CAM simulation ensures collision–free operations, optimized cutting strategies, and accurate reproduction of the gear design. This process is crucial since the spur gear plays a central role in torque amplification and power transmission between the crank handle and the rollers.

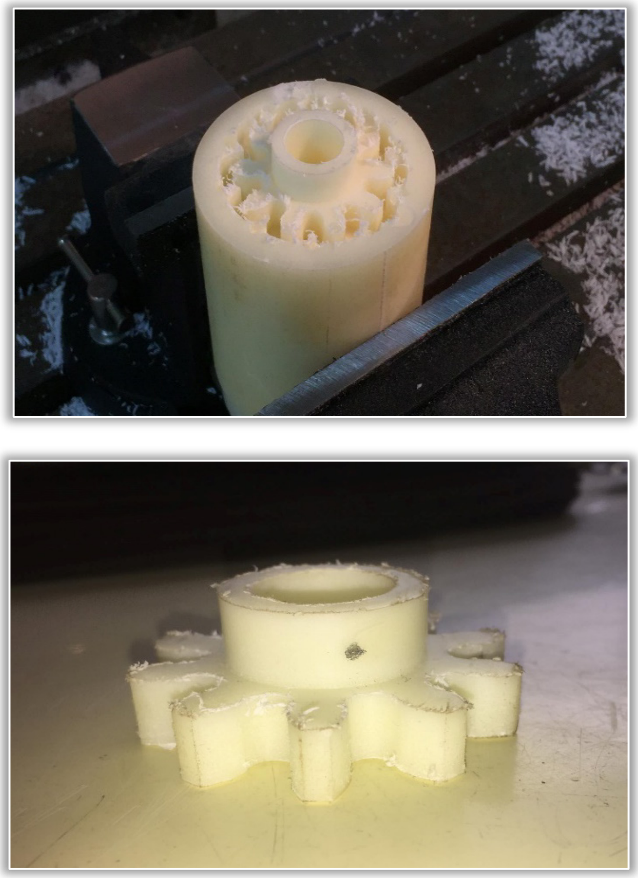

Figure 8. The experimental machining and final product of the spur gear

Figure 8 presents the experimental results of spur gear fabrication through CNC milling. The left–hand image shows the gear during machining, with the blank material mounted on the milling table and partially machined teeth visible. This intermediate stage highlights the accuracy of the programmed tool paths in progressively shaping the gear profile.

The right–hand image displays the completed spur gear, fully separated from the blank. The finished component exhibits well–defined gear teeth and a central bore suitable for press–fitting onto the roller shaft. Minor surface marks from the milling process are visible, but the overall dimensional accuracy and profile fidelity are consistent with the CAD model and CAM simulation shown in Figure 7. This result validates the transition from digital design to physical manufacture, confirming that the gear can reliably function as part of the 4:1 reduction system for torque amplification in the mini sugarcane press.

RESULTS AND DISCUSSION

Figure 9 provides a comparison between the digital design and the fabricated prototype of the mini sugarcane press. The left–hand image presents the 3D CAD assembly model created in Siemens NX, illustrating the integration of the crank handle, spur gear transmission, and paired rollers within the supporting frame. The model was used to validate dimensional accuracy, alignment, and functional relationships prior to manufacturing.

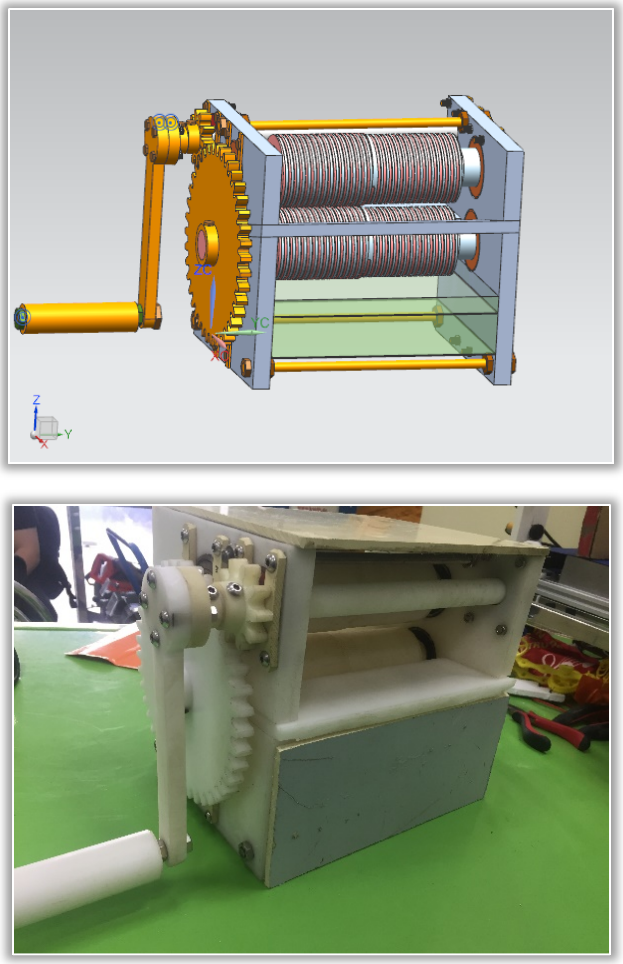

Figure 9. Assembled Prototype of the Mini Sugarcane Press

The right–hand image shows the assembled physical prototype, in which the machined components—including rollers, gears, and side plates—were fitted and secured using fasteners and bearings. The assembly confirms the successful translation of the CAD/CAM design into a functional product. The prototype demonstrates smooth roller rotation, proper gear engagement, and structural stability under manual operation.

This direct comparison highlights the effectiveness of the CAD–CAM–CNC workflow in bridging the digital model and physical realization, thereby validating the design methodology applied in the development of the mini sugarcane press.

Although the mini sugarcane press prototype successfully demonstrates the feasibility of an end–to–end CAD–CAM–CNC workflow, several limitations are evident. First, the choice of POM plastic for gears and frame plates reduces cost and simplifies machining but compromises durability, wear resistance, and hygiene compared to metallic alternatives such as stainless steel. Second, the rollers are manufactured with smooth cylindrical surfaces, which limit the gripping efficiency and juice yield; surface texturing or knurling would likely improve performance. Third, the device relies exclusively on manual operation via a crank handle, restricting throughput and increasing operator fatigue, thereby reducing its applicability beyond educational or demonstration contexts. Fourth, the roller nip gap is fixed at 0.8 mm and cannot be adjusted for different cane diameters, which limits adaptability. Fifth, while the design and manufacturing validation were successful, quantitative performance testing in terms of juice extraction efficiency, throughput capacity, and input–output energy balance was not undertaken. Finally, safety considerations, such as guards for gears and rollers and ergonomic enhancements for the crank, remain absent and would be necessary for wider practical deployment.

CONCLUSION AND FUTURE WORK

This study presented the design, fabrication, and assembly of a compact hand–cranked two–roller sugarcane press using a fully integrated CAD–CAM–CNC workflow. The design was based on experimental torque requirements and implemented through a 4:1 spur gear reduction system, ensuring adequate amplification of human input for juice extraction. The major components—including rollers, spur gears, and side plates—were successfully modelled, simulated in NX CAM, and manufactured on CNC machines with high dimensional accuracy. The assembled prototype validated the effectiveness of the digital–to–physical process chain and demonstrated smooth roller motion, proper gear engagement, and sufficient compressive action for small–scale sugarcane pressing.

Despite these achievements, the study also revealed several limitations. The use of POM engineering plastic for gears and frame plates reduced long–term durability, the rollers lacked optimized surface texture for efficient gripping, and the fixed 0.8 mm nip gap limited adaptability to different cane sizes. Furthermore, performance metrics such as juice yield, throughput rate, and operator effort were not quantitatively assessed.

Future work should therefore focus on addressing these issues. The use of stainless steel or other hygienic and wear–resistant materials is recommended to enhance durability and food safety. Surface modifications to the rollers, such as knurling or texturing, should be investigated to improve cane feeding and extraction efficiency. Introducing an adjustable nip gap mechanism would increase adaptability for varying stalk diameters. Motorization of the crank system could expand the applicability from educational and demonstration contexts to semi–industrial use. Finally, systematic performance evaluation—including yield efficiency, energy balance, and long–term operational stability—should be conducted to provide a comprehensive assessment of the press's effectiveness.

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