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| RESEARCH ARTICLE

Innovative Redesign and Cost Optimization of a Smart Etching Press: Transforming Printmaking Education in Resource-Constrained Contexts

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| ABSTRACT
The Smart Etching Press reimagines antiquated printmaking technology to create a portable new art tool for limited resource regions like Bangladesh by pairing 3D-printed ABS roller cores with stainless-steel sleeves, HDF-stainless hybrid beds, and modular iron frames. Through the friction-driven synchronization, rough-grain grip stickers, spring-loaded pressure-holding system, and stainless bearings, this machine delivers equivalent performance of a professional-level relief and intaglio press. It addresses the cost, weight, and accessibility barriers in printmaking education systems. It breaks down for transport and is compatible with basic tools at a fraction of the commercial alternatives: less than half anything. Apart from fulfilling its functional role, it also stimulates transdisciplinary learning with engineering, materials science, and printmaking as a local innovation and self-sustaining force that drives the whole community. It is a straightforward construction that formally ties complex manufacturing to artistic practice, enabling printmakers to print independently of expensive commercial imports.

| KEYWORDS

Printmaking, Smart etching press, Low cost, Portable.

| ARTICLE INFORMATION

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1. Introduction

1.1 Rethinking the Etching Press for a New Generation

One of the biggest obstacles in printmaking education today is the expense and difficulty of traditional etching presses. This gridlock is standing in the way of countless schools and artists that could be making print, because they do not have access to professional-quality printmaking equipment, which limits the growth and democratization of printmaking as an art form (Leaf, 1984).

Printmaking has been an important form of communication for many thousands of years, and historical evidence dates the practice back to as early as 175 A.D. in China (Eppink, 1971). Printmaking is the process by which an image is transferred from one surface to another. There are four ways of printmaking.

- Relief process
- Intaglio process
- Planograph
- Serigraph

In the process of printmaking, imagination is put on the surface or paper called layout, to prepare a block, by which it is possible to create more editions of a masterpiece artwork with the same artist.

Printmaking, made by applying various techniques, is capable of giving birth to new ideas and arriving at a new stage. Graphics are no longer just prints. Graphics have now become a high-quality art form. In which lies the great potential of epoch-making revelation (Nag, 1987).

So it can be said, Printmaking is a basic art medium with a lot of potential. Presenter of a serious, aesthetic, thoughtful artistic structure that is capable of manifesting itself in terms of its own characteristics.

Press is essential in completing the printmaking process. Specifically, the etching press: A lot has changed in the etching press since artists used acid to cut designs out of metal plates in the 15th century (History of etching and printing, 2024). Modern commercial etching presses, however, range in price from 2,00,000 to 5,00,000 BDT, which renders these presses too expensive for many educational contexts.

Today, we know that many traditional printing presses are rather bulky, costly, and require particular expertise to run efficiently (Etching press specifications and costs, 2024). It also poses a significant challenge for aspiring artists and resource-strapped educational institutions. The solution is further complicated by the mechanical nature of many existing designs that depend on heavy steel construction and tight engineering tolerances.

This particular printmaking press has a unique assembly mechanism comprising multiple key components. Here's a simplified overview:

Frame: This gives structural support to the press. It usually consists of heavy materials like steel or cast iron.

Rollers: The press has a double pair of rollers, bearing tired. One roller is attached to a handle or a crank, while the second roller is not moving.

Bed: This is the flat surface of the printing press where the printing surface (such as a plate or block) and paper are placed for printing.

Pressure Adjustment Mechanism: We have a way to control the pressure that the rollers apply to the print bed and the paper. This can be done via a threaded system or through other pressure adjusting systems.

Lever or Crank: The press is operated by means of a lever or crank. It gets the rollers to turn (one way or another) and presses the printing surface onto the paper. Mainly, we put these pieces and other necessary items together to form a classic etching press, and we get the equipment that is extremely expensive.

Press design offers new possibilities through recent innovations in materials science and manufacturing technology. Combining this with advanced lightweight materials, including aluminum alloys, advanced polymers, and composite materials, can provide possibilities in minimizing weight and cost without compromising structural integrity (Fick, 2015). The design of this new kind of "smart etching press", as presented here, forms a direct response to that challenge by identifying modern engineering techniques consistent with traditional printmaking practices. All these design materials are used instead of solid steel rollers and bulk cast iron frames: 3D-printed ABS for the roller core, stainless steel where surfaces and shafts need to be hard, high-density fiberboard, including a thin SS sheet for the bed, and a modular iron body structure which could be completely disassembled in case transport is required. Re-engineering each of these subsystems individually, the rollers, side frames, bed, drive mechanism, grip technology, pressure control, and assembly strategy, such that the Smart Etching Press is more than just a cheaper design of commercial presses, but instead a revolutionary tool, one that fashions uncommon collaboration between technically adept fabrication apparatuses and inexpensive art pedagogy.

The press serves as an example of how locally available materials, 3D printing, and appropriate engineering can be used to create high-quality studio equipment at lower costs than machines made by international brands. Though a branded tabletop etching press from foreign suppliers can easily range from hundreds to several thousand dollars, depending on size and brand name, this design can be made for a fraction of the price while still maintaining professional-grade functionality, making it a compelling case study in economical innovation in printmaking.

In short, the importance of this smart etching press lies in its potential to transform printmaking education by providing access to professional equipment for a broader range of community educators and students. The project seeks to support the preservation and proliferation of traditional printmaking techniques in a contemporary educational context by counteracting essential barriers related to cost and access.

2. Design Philosophy and Objectives

The key priorities for the Smart Etching Press are accessibility, portability, and print quality, which are reflected in material selection and mechanical design.

Accessibility allows anyone to construct it with traditional metalwork, ABS filament 3D printing, and readily available hardware.

Portability makes the overall weight figure ultra-light for structural safety, allowing easy disassembly into a bag.

Print quality provides pressure that is constant, high, and uniform over the usable printing width and produces minimal vibration or slippage, or misalignment, crucial for relief and intaglio methods.

This smart etching press makes it possible to create in the studio when etching presses are both expensive and notoriously huge, and turns this model into an accessible, portable reality that anyone can make. Key objectives achieved include:

60–70% lower costs than conventional presses (less than 100,000 BDT total), remove the barrier of entry for artists from all economic strata (including students and emerging talent) to be able to print professionally. The quality and utility remained intact, even with a low price point.

True portability means students can practice anywhere without bulky barriers holding them back; heavy and expensive materials are replaced in the accessories with lightweight alternatives, reducing weight by over 80%.

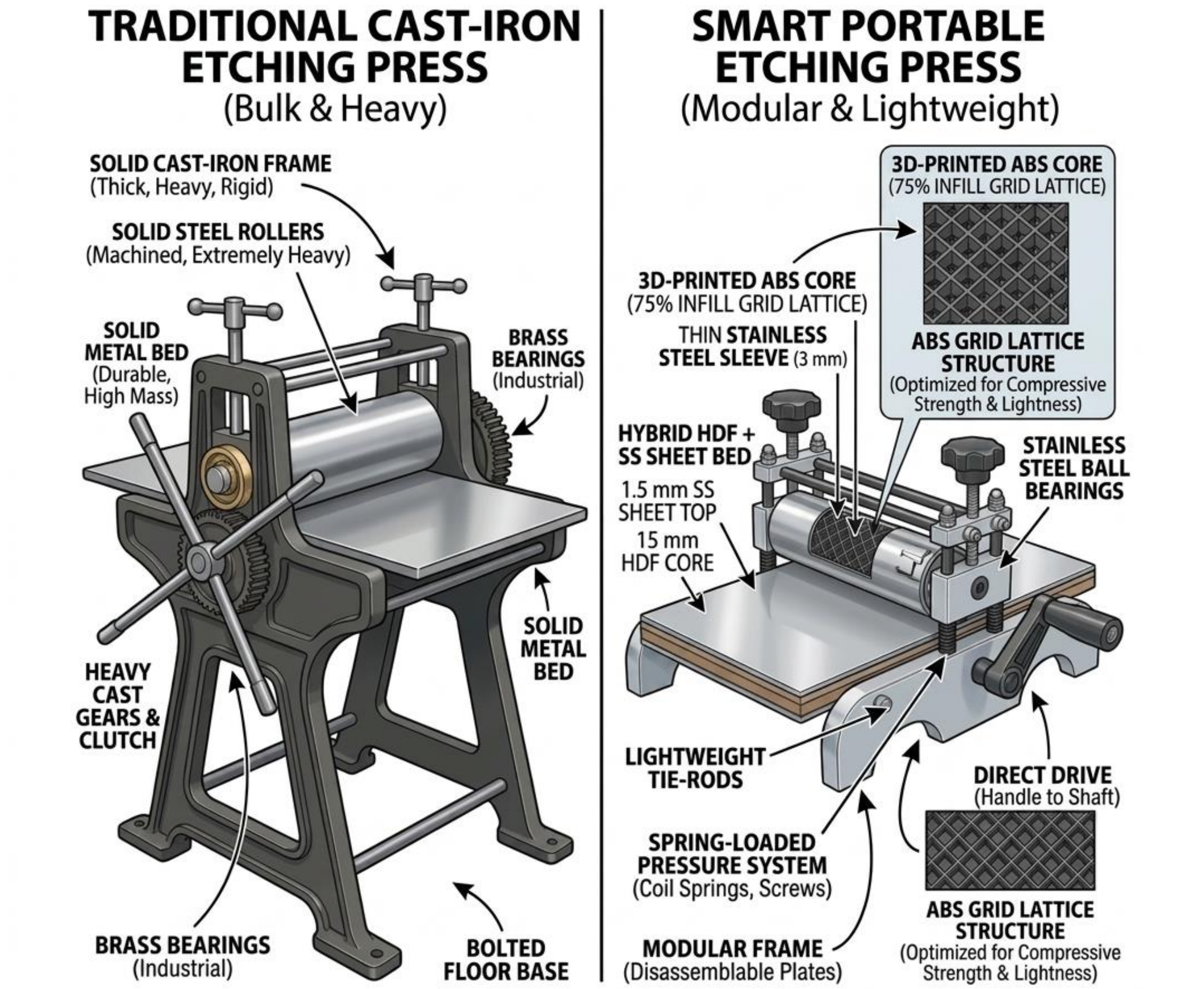

Figure 1: A structural and material comparison between a traditional cast-iron etching press and the new Smart Portable Etching Press.

3. Technical Overview: Dimensions and Core Architecture

In the first phase, I conducted a systematic review of existing printmaking literature, examining both historical development and contemporary innovations in press design. Select earlier works such as Leaf's intaglio printmaking techniques (Leaf, 1984), a comprehensive analysis by Eppink on 101 printmaking processes (Eppink, 1971), and recent materials science coverage pertinent to art equipment. This review revealed important knowledge gaps related to cost-effective press design and indicated room for innovation in materials selection as well as manufacturing processes. Analysis of the historical press design indicated that many traditional designs had not changed in hundreds of years, thus providing the opportunity for updates to the traditional press.

The general architecture of the Smart Etching Press can be regarded as the synchronized interaction of three major subsystems: roller assembly, side body support structure, and printing bed, each carefully tuned to work together under load. The press has a 45 cm span between the rollers, allowing artists to print comfortably on standard-sized sheets just shy of that width, and the bed is 70 cm long and 45 cm wide, which provides adequate run-up space so the plate and paper can completely cross through the nip between the rollers as well as adequate areas for registering at either end. Dimensioning is crucial since it allows the press capability to be used for smaller experimental plates, but also other larger compositions that might be treated in academic environments.

The 30 cm of side body height provides sufficient vertical space for the rollers, bed, and spring-loaded pressure system. From a structural perspective, the main side frames are cut from solid iron plates having 15 mm of thickness, selected for maximum stiffness and load-bearing capabilities in order that when the top roller is pressed downward with high force, the frames do not bend or twist. Four stainless steel support rods (15 mm diam) further tie the two side plates and lock them parallel to each other, which reduces vibrations by an order of magnitude. Combined, these design elements build a solid mechanical base that allows the more specialized innovations, such as the 3D-printed roller core and rough grain grip system, to work consistently.

4. Roller Assembly: Engineered for Strength and Lightness

The roller assembly, which is the heart of any etching press and responsible for applying pressure and moving the bed through a rolling motion, is both structurally sound and a new way of operating in the Smart Etching Press. Each roller is 45 cm long and has a diameter of 8 cm, chosen as they produce a sufficiently sized roller to spread pressure while being compact enough to limit material usage and keep torque requirements within reason on the equivalent-sized handle. The large diameter allows the roller to ride over minor irregularities in the plate and packing layers with less risk of creating a flat spot or localized overpressure, which could damage the paper or distort the image.

The Smart Etching Press uses a hybrid construction involving a 3D-printed ABS core with a hollow stainless-steel sleeve (3 mm thick) around the surface and a solid internal differentially small-diameter steel shaft through the core to connect to bearings, a handle, etc., rather than extremely heavy and expensive-to-make or import machined solid-steel rollers. Such a layered approach enables each material to perform its best role: ABS enjoys the bulk volume and structural capabilities of being light yet still capable. Stainless steel provides a hard, corrosion-resistant contact surface while the internal steel shaft safely carries bending and torsional loads into the guide's side frames. What you end up with is a roller that looks and behaves like a traditional steel roller when in use, but has far less weight and costs much less to manufacture.

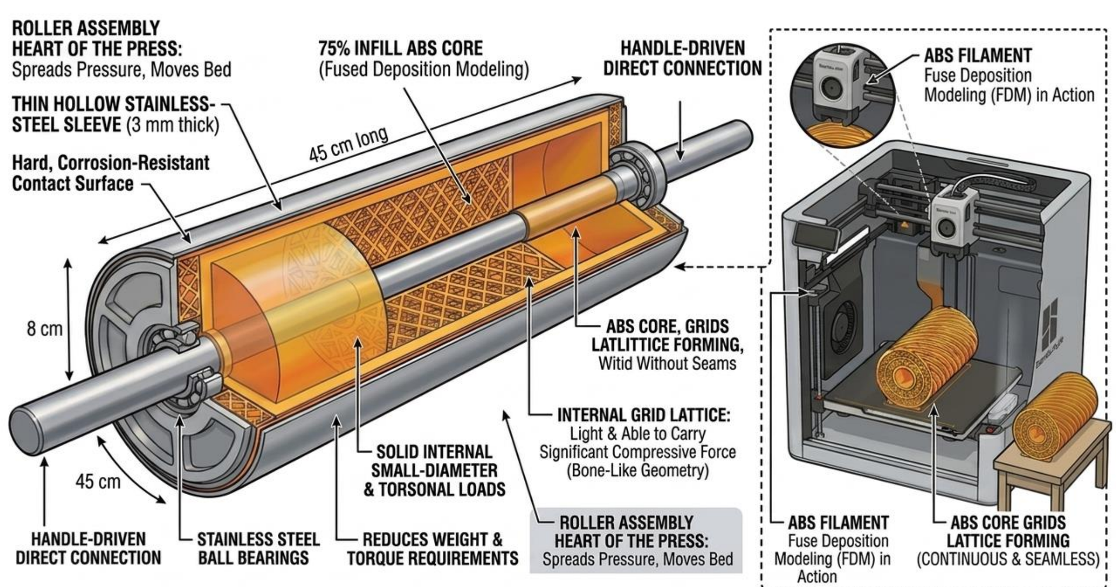

Figure 2 Roller assembly & 3D Printing process

5. Material Science in Practice: Why ABS for the Roller Core?

Acrylonitrile–butadiene–styrene (ABS) is among the most widely employed materials in fused deposition modeling (FDM) 3D printing, and it is particularly suited for engineering contexts that require toughness, impact resistance, and moderate thermal stability. ABS can resist repeated loading and small deformations without cracking (a problem with much more brittle materials, such as PLA), so it's an excellent candidate to manufacture a structural core intended to receive compressive and shear forces during each printing cycle. Mechanical characterization studies on parts manufactured by 3D printing using infill approaches, resulting in various amounts of material being used (as a percentage). When printed with optimized parameters and reasonably high infill densities, ABS can have compressive strengths on the order of tens of megapascals, sufficient to withstand the distributed loading experienced within roller cores when loads are spread across supporting components (in this case, a stainless-steel shell surrounding an ABS liner).

The ABS roller core of the Smart Etching Press is 75 percent infilled with a "grid" design in order to build an internal lattice structure that is both light and able to carry significant compressive force. It resembles the internal geometries of natural bone in that its strength emerges through an optimized configuration of materials instead of brute mass. Already, as a continuous solid, it has no weak adhesives or seams locking the core together. Using ABS like this and turning what we have previously thought of as a prototyping material into a workable structural element shows how additive manufacturing can be taken beyond just mockups, right through to real production-grade art equipment components.

6. Side Body and Support Structure: Building a Stable Frame

Rolling machine parts. The rollers are the most visible moving elements of the press, but their performance heavily relies on stability, which is delivered by the side body and base support structure. For this design, each side body is made from a 12 mm thick solid iron plate due to its excellent stiffness and durability, which are also easy to work on by drilling or turning in a simplified metal shop. The plates are thick enough that the side frames themselves do not bow in or out even under heavy clamping forces from the spring-loaded pressure system, thereby keeping the rollers parallel and maintaining an even nip across their length. If the frames were lean or composed of a less inflexible material, such distortions could cause uneven tension and visible artifacts in the printed image.

Four stainless steel rods, 12 mm in diameter, link these side bodies together in a rectangular fashion to connect the upper and lower halves of the frame. The rods act as structural braces, keeping the side plates at a consistent spacing apart, virtually eliminating any twisting or vibration of the press during operation. As it operates, the torque used through the handle, combined with the resistance of the plate and paper, can create lateral forces attempting to rack the frame, but the rods will resist this motion, making one big solid block out of all assemblies. The rods have a structural function but also allow for some convenient mounting or alignment points during assembly, and they can be quickly removed when the press needs to be taken apart and transported.

7. Printing Bed Design: A Hybrid of HDF and Stainless Steel

The printing bed is where the artistic and mechanical aspects of the press converge, as it must be at once flat, smooth, durable, and compatible with the grip system that moves. The Smart Etching Press has its bed built from a 70 cm×45 cm, 15 mm thick high-density fiberboard (HDF) panel, which provides a rigid, dimensionally stable core that helps reduce warping in the work area when properly sealed and supported. HDF is an affordable material, available in most areas, and provides a reasonable ratio of stiffness to weight, which all combine into making it a good construction for a bed intended to be moved and handled regularly. However, exposed HDF by itself is not great for long-term printmaking applications because it can dent and get wet, causing swelling or ink absorption.

To remedy this, a 1.5 mm thick stainless-steel sheet is glued and mechanically attached onto the HDF bed top surface, providing a composite rail structure of high stiffness due to the bulk stiffness given by the HDF, as well as offering a hard, smooth, and ink-resisting top surface material. Thin enough to keep weight down and thick enough to take a beating from piles of plates and paper, not to mention minor impacts when working in the studio. This combined bed glides through the lower roller and under the upper roller without noticeable deflection, ensuring that consistent contact pressure can be maintained at the printing line. The press saves mass and cost by building the bed as a hybrid element, not a solid metal slab, which gives a working surface that meets professional expectations.

Figure 3 Bed composite with HDF & SS

8. Drive System: Handle-Driven Efficiency without Gears

The Smart Etching Press' drive system is a simple but clever arrangement; instead of relying on a complex set of gears or chains to reduce the motion from spinning the handle, it uses a direct mechanical connection between the handle and the lower roller. With this design, the handle is secured directly onto the steel shaft of the lower roller, and turning the handle causes both rollers to turn in unison; friction pulls the bed through the roller gap. As the bed rests right on top of that lower roller, the movement is smooth and, importantly, directly coupled to the rotation of the roller, so no mechanical gearing in between creates less backlash, noise, and maintenance burden.

As a result, this direct-drive approach puts the motion of the press at a very beginner-friendly level; they can see and experience instantly how much the bed moves when turning the handle. This could be a steady ratio; as an example, every turn of the handle moves the bed approximately one roller circumference forward. This can be used to estimate how many turns are required to fully pass a plate through the press. This ease of mechanism also aids reliability, with fewer parts prone to wear or misalignment over time, and reduces fabrication requirements. Machining a shaft for the reception of a handle is far less strenuous for a local shop than cutting the custom gears on which the deal relies, as well as sourcing tight tolerance gear sets. The underlying drive system of the Smart Etching Press is selectively simple but thoughtfully designed; rather than pushing through a more complex arrangement of gears or chains, the handle rotates the lower roller directly via a rigid mechanical connection. With this architecture, the handle attaches directly to the steel shaft of the bottom roller so that as a user turns the handle, both rollers turn in unison and friction draws the bed through the roller gap. This is possible because the bed rests straight on top of the lower roller. The motion is thus inherently smoother and synchronized with the turning of the roller, while there are no intermediate parts like gears to lead to backlash, noise, or maintenance.

Instead, the press uses a direct drive approach that results in highly intuitive motion for beginners since they can visually and physically immediately relate how far they rotate the handle compared to how far forward their bed plunges. For instance, there will be a fixed ratio of one complete turn of the handle moving the bed roughly one roller circumference distance, and so this can be used to calculate how many turns are required to pass a plate fully through the press. The straightforwardness of the mechanism also adds to reliability, with fewer parts likely to wear or misalign over time, as well as keeping fabrication requirements modest; machining a shaft to accept a handle is vastly simpler than cutting custom gear teeth or hunting down exacting gearsets.

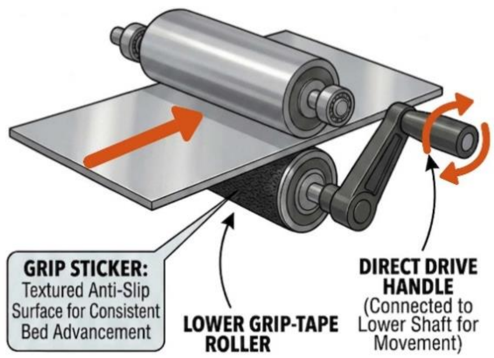

Figure 4 Handle Driven Efficiency without Gears and create friction.

9. Synchronization of Upper and Lower Rollers through Friction

Instead of gear trains used in some larger industrial presses to mechanically synchronize the rotation of the upper and lower rollers, the Smart Etching Press uses friction-based synchronization provided by the bed as a mediator. Here, the lower roller is the one driven by the handle only, and because it causes only an upper free-running roller to turn when you pull a sheet of paper under it by contact (the latter slowly turns over its own axis on top of your bed). If everything is properly tuned and the printer is loaded properly, then the static friction between the bed and upper roller will be enough to guarantee that the upper roller spins at a proper speed respective to bed motion, preventing print dragging or smearing.

In addition to mechanical simplicity, there are several other significant advantages to this arrangement. Firstly, the design removes the requirement for matched gear pairs on each roller, decreasing production difficulty and cost, which is beneficial in low-resource settings when precision gear cutting may not be widely available. Second, friction-based synchronization is somewhat self-compensating: any small differences between roller diameter, bed thickness, or packing layers are automatically compensated by the system, as the real velocity of the upper roller will always be determined by how fast it needs to move if limited to pull the bed along with it. Finally, since the gears do not interlock, the press is quiet and less ominous to new users, as well as a helpful reminder that this design really embraces accessibility and ease of use.

In order for a friction-driven press to operate reliably, the lower roller needs to make contact with the bed in such a way that slippage will not occur while under load, especially when printing thicker plates or when higher pressures are used. To overcome these issues in the Smart Etching Press, they use “rough grain stickers” (adhesive sheets having intentionally rough surface texture) on the outside surface of the lower roller and on the bottom face of the bed at some place where both meet. Both applications do quite well to increase the coefficient of friction between roller and bed, converting their interface from a pair of smooth metals that may be able to slide past each other into a tightly gripping set of surfaces engaging in something more like intermeshing textures.

Essentially, it's the operational equivalent of fine-grit sandpaper but without the damage or uneven pressure that would be caused in order for a traditional stick to bite into the bed; instead, these grain stickers bring just enough micro-interlocking between the surfaces so that when under operator load, a roller will "bite" and grip onto the bed. This makes such contact much stickier, so when the handle turns, the motion of the roller passes directly into the bed and thus enables heavy plates, thick stacks of paper, and blankets really to be pushed through without losing grip. Moreover, stickers have an added advantage of maintainability: if they wear out or get really dirty because of ink and other debris, you can just peel them off and replace them to restore the grip performance without changing any metal part.

10. Pressure Control: Spring-Loaded Adjustment for Consistent Prints

Controlling and tightening the pressure of the top roller to the plate and bed is a fundamental requirement in any etching press, as printmaking techniques and materials require specific pressure profiles for best results. The Smart Etching Press accomplishes this by using a spring-loaded mechanism on the individual adjustment screws that extend through a heavy-duty coil spring and attach to a pressure bar located above the upper roller. As the user tightens or loosens these screws, they compress or release the springs, which alter the vertical position of the pressure bar.

The springs make a significant contribution of mechanical compliance to the system, which enables it to absorb shocks and tolerate small changes in plate thickness or paper layering without sudden spikes in pressure. When the roller rides over thicker spots, the springs compress momentarily so that force isn't applied all at once, adding too much rigidity and danger to both paper as well as causing streaks and distortions. This inclination to “float” slightly above imperfections produces the sharper and clearer prints seen because it keeps the contact pressure in a relatively stable range, rather than spasmodically swinging. The spring-loaded system is also helpful for students and new users because it simplifies the process of identifying an acceptable pressure setting that works over a broad range of plates and papers, minimizing damage when starting out.

10.1 Bearing System: Ensuring Smooth and Silent Rotation

To ensure user comfort, not to mention that the motion and pressure on each sheet remain consistent across the entire printing process, those rollers turn smoothly as a result of a total of six high-grade stainless steel ball bearings in the Smart Etching Press. Each roller shaft pivots in bearings that are housed within the side bodies, allowing them to spin freely with negligible friction as the handle is rotated, while the choice of corrosion-resistant stainless-steel construction will ensure long-lived and reliable operation from humid spaces or studios where temperature and moisture control may not be perfect. Quality bearings require less torque to turn the press, allowing users of any strength level to crank the handle effortlessly through a full printing stroke.

This is because the bearings allow for rotation to occur within, and very small amounts of misalignment due to imperfections in the shaft can be isolated by design through a type of decoupling of rotational motion from the side frames as well. This means the press works quietly and with a level of mechanical sophistication usually believed to be only found in far more expensive gear during use, improving the sense of control and inclusion by the user. By lowering friction, less wear occurs not only on the shafts but also on the bearing housings, assisting with longevity, a key feature for an educational press that will likely see daily use by numerous students during its lifetime as a part of studio equipment.

11. Modular, Part-by-Part Assembly and Portability

One of the standout features of the Smart Etching Press is its modular architecture, which allows the entire machine to be disassembled into a set of manageable components that can be packed, transported, and reassembled with relative ease. The assembly process begins by placing the two iron side bodies on a sturdy table or workbench, aligning them so that their corresponding holes for the rollers and support rods face each other. Next, the upper and lower rollers are inserted into their respective bearing housings on each side, ensuring that the shafts seat properly and that the roller surfaces are parallel, after which the stainless-steel support rods are slid through their holes and secured with nuts, locking the frame into a rigid rectangular shape.

Once the frame and rollers are in place, the handle is attached to the shaft of the lower roller, typically using a keyed connection or a pinned joint to ensure that it cannot slip under torque, and the bed is positioned so that it rests on top of the lower roller and passes under the upper roller. The spring-loaded pressure bar is then installed above the upper roller, with the springs and adjustment screws threaded into their mounting points, allowing the user to fine-tune the pressure as needed. Because each of these steps can be carried out with basic hand tools like wrenches and hex keys, and because no part is excessively heavy, the press can be fully assembled or disassembled in a short amount of time, making it highly suitable for workshops, temporary studios, or situations where equipment must be shared or stored compactly between sessions.

12. Cost Management: Material Choices and Economic Impact

Reducing the financial threshold for owning or deploying a competent etching press is one of the biggest drivers behind Smart Etching Press, but it comes with spellcheck capabilities. Professional, commercial tabletop etching presses from reputable brands can run anywhere from several hundred dollars for basic beginner models to many thousands of dollars for industry-acclaimed presses with large beds and robust frames, far away from the budgetary grasp of so many individual artists and smaller institutions. Meanwhile, the Smart Etching Press saves substantially by material substitution, modular design, and more importantly, the omission of certain high-value parts while still providing a reasonable working machine.

Replacing a complete solid steel roller with a core of 3D-printed ABS clad in a sleeve of stainless-steel saves material and machining costs, which contributes around 50-60% cost savings relative to traditional construction on estimates from the modular roller assembly. In addition, as the bed is built from HDF with a top layer of thin SS sheet, this results in an estimated cost saving of 70% when compared to a fully metal bed of similar area, and mounting the entire press directly onto a table rather than on a dedicated metal base plate represents an extra 100% cost saving for this item. Modularity actually pays off even for the side bodies; after all, it is significantly cheaper to use flat 12 mm iron plates that can be cut and drilled locally than to import complex cast frames. This brings the total build cost for the Smart Etching Press down to many orders of magnitude below that for comparable presses available commercially, enabling institutions to construct multiple units or enabling students themselves to make their own as part of project-based learning.

13. Conclusion

The Smart Etching Press is an excellent case study in how modern engineering tools and methods like 3D printing, modular design, and the careful selection of materials can be used to reshape traditional art equipment into forms that dramatically reduce barriers to access while maintaining high performance. The ABS-cored, stainless-sleeved rollers and HDF with SS bed strip are heavy, expensive components compared with the intelligent alternatives. Not only does it give you a functional printing press, but as an educational object, there are many lessons in mechanics, materials, and the combination of technology with craft and creativity.

In place of the costly, traditional presses housed in art institutions worldwide, this press can serve as a shining example (being that some cost structures become moot) for local needs and engineering ingenuity and tradition to meet artistic aspirations with functionally enhanced opportunities rather than barriers. Students build, modify, and print with this press, engaging more broadly in the narrative of empowerment: proving that sophisticated high-impact tools do not need to be purchased at great cost from foreign countries but can be imagined locally and built from raw materials in shops and studios. Essentially, the Smart Etching Press is not just a machine but also a platform to enable and explore ongoing experimentation, adaptability, and collaboration that might extend the horizons of printmaking education & creative practice in Bangladesh and beyond.

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