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Review Article

# Comparative Study Between Milling and Laser Beam Machining to Produce Quantitative Surface Modification of Metal Products and Jewelry (in the Engraving Field)

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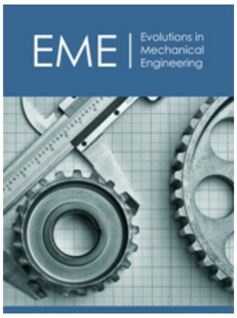
**ISSN: 2640-9690**

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**Submission:** November 20, 2025

**Published:** December 11, 2025

Volume 6 - Issue 3

**How to cite this article:** Abdelrahman Abouzaid*. Comparative Study Between Milling and Laser Beam Machining to Produce Quantitative Surface Modification of Metal Products and Jewelry (in the Engraving Field). Evolutions Mech Eng. 6(3). EME.000640. 2025.
DOI: 10.31031/EME.2025.06.000640

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## Abstract

Processing and operating the surfaces of products by milling or laser beams and adding and forming models of traditional and composite materials by milling or laser have become applied in many different industrial fields and on a large scale today. Laser beam-operated production is classified as one of the directions that rely on photovoltaic operation, or what is known as electro thermal. The mechanism of operation depends on the use of electrical energy to convert it into light or heat energy. Milling operation is also classified as an electromechanical operation, in which the mechanism of operation depends on electro-mechanical energy to convert it to mechanical or kinetic energy. The research aims to conduct a comparative study between milling and laser machining in which the advantages and disadvantages of each technique are identified. It is clear to us that laser beam machining technology is an outstanding technology in solving the mass production requirements in the field of machining surfaces of metal products and jewelry. And an advanced alternative to milling technology. The study is based on the descriptive analytical approach. It has been possible to summarize the advantages of both operations by machining with milling (routers) and operations by machining with laser beams within the manufacturing processes in production through the current study.

Through research studies and surveys of production units specialized in the field of machining on surfaces, it was found that many mechanisms and machines. With which treatments of designs, data, decorative drawings and images can be carried out on the surfaces of the vocabulary of jewelry and metal products with different mechanical techniques. Leading to slow and limited production or single production "one-piece system" Here began the problem of research in the introduction of technologies to meet the requirements, which leads to the need to use an alternative and advanced technology. Milling machining does not meet the requirements of modern operation, and it takes time, effort and money. Most of the operating technologies known to the market are limited to the production of one-piece operation. This obliges specialists to seek the use of advanced alternative technologies to cover mass production in the field of operating product surfaces. Thus, the study deals with the most important solutions related to the operation of surfaces with both milling and laser beams.

**Keywords:** Machining operation; Industrial laser; Mechanical milling

## Introduction

The design of metal products and jewelry is related to production. Since the 1970s, the uses of milling production and high-energy laser beam operation have been increasing in the industry day by day [1]. The processes range from perforating, cutting, welding [2,3], hardening, processing product surfaces, modifying surface properties, numbering, building models with metal or plastic ores (rapid modeling), deep drilling, and engraving. Particular mention here is made of milling machining and laser machining. The use of advanced technology meets the requirements of modern operation of product surfaces and jewelry. And the desire to find practical solutions, fast, running and large production of commitment to customers. Keeping pace with rapid technological development [4] clearly shows the importance of the study. The high strength of the milling head, the high temperature of the lasers and the concentration and precision of both are the main reasons for wide applications in many fields and on a large scale. The milling force applied to the surface reaches thousands of newtons. The surface on which the beam is located reaches thousands of degrees in less than one second [5]. Milling or bundling can run or build product models from conventional or composite materials [6].

Technological systems use production processes. While people have the knowledge to design products, some have the know-how to develop processes. While others have the know-how to operate machines, another group has the know-how to operate product surfaces. Milling is classified as an electromechanical process in which the operation depends on electromechanical energy, so the electrical energy is converted into mechanical or kinetic energy. The laser is also classified as a direction based on photoelectric (thermal) operation, in which the mechanism relies on the use of electrical energy to convert it to photo electricity (thermal) [4]. Modern processes such as laser engraving use unconventional mechanisms to remove part of the surface of the metal ore. Do not use a machining tool as in conventional operations that use a sharp tool in operation. Milling uses a sharp machining tool as in normal operation. Research studies and surveys of production sectors specialized in the local, regional and global market in the field of surface machining. Many of the mechanisms by which designs, data, drawings and images can be processed by machining on the surfaces of jewelry and metal products with different mechanical techniques have been found to perform inflexible operation and depart from the advantages of modern operation. The study will compare both milling and laser machining to develop the advantages of each technology.

## 1- Milling Engraving Machining

Milling machining is a post traditional process, using some form of mechanical energy and differs in the effectiveness of the milling machine tool [7]. Machining is done by removing part of the metal surface [4], and Figure 1 shows the course of the EGX-20 milling process (http://www.rolanddga.com/products/engravers/egx20/). Table 1 shows the basic operating factors in milling machining. Figure 2 the method and tools used in milling machining operation (http://www.datron.com/products/mini-tools/micro-tooling.html). Milling machining is used in some areas of products and jewelry in machining 2D flat surfaces as in Figure 3, awards, product pin and accurate guide marks, personal jewelry and the ability of milling machines to build small projects. The machines include an electronic line engraving program. Figure 4 shows an inscription for the painting (http://www.rolanddga.com/products/engravers/egx20/brochure.asp?). Figure 5 is an example of engraving the rotating surfaces of products (http://www.rolanddga.com/solutions/awards/). Figure 6: An application for engraving the surfaces of a group of metal products (http://www.rolanddga.com/solutions/adasignage/).


**Figure 1:** Shows the course of the milling machining process.

**Table 1:** A set of diverse factors resulting in a process that is normal [4].

| Basic Operating Power Fundamental Machining Energy | Remove from Work Piece Removal | Transfer Medium | Energy Source | Process of Elimination. Material Removal Process |
|---|---|---|---|---|
| Mechanical mechanical | Share | Physical connection physical contact | Cutting tool | Pre-traditional machining |

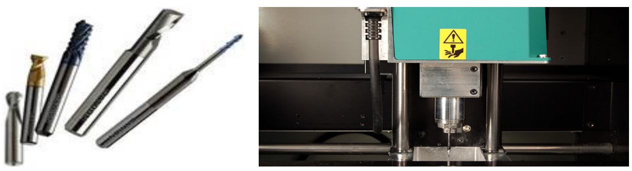

**Figure 2:** The method used in operation by milling and machining head and to the left of the milling tools.

**Figure 3:** Shows the excavation of flat surfaces 2D.


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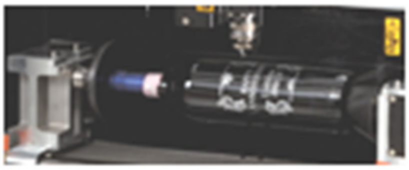

**Figure 4:** With an engraving of the painting.


**Figure 5:** Example of engraving the rotating surfaces of the products.


**Figure 6:** An application for engraving the surfaces of a group of products.

Figure 7 shows the deep milling of rough-touch material with a machine produced by DATRON company, in addition to laser machining, which does not allow this feature. This type of precision machine also allows flexibility in machining the material at any depth. In this part, it is better than laser machining for applications that require machining depth. Figure 8 shows the manufacture of a brass mold with milling with dimensions of 30x40 inches, Figure 9 shows the formation of an aluminum mold, Figure 10 shows the milling of a part of stainless steel and Figure 11 shows the machining of a wax model of a piece of jewelry.

**Figure 7:** Deep milling of rough texture material.

**Figure 8:** Shows the manufacture of a brass mold with milling.

**Figure 9:** Milling formation of an aluminum mold.

**Figure 10:** Milling of a part of stainless steel.

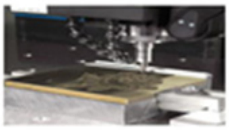

**Figure 11:** Machining a model of wax for a piece of jewelry.

The Figure 12 deep milling of a mould of menium, the Figure 13 milling of a medallion mould of steel negatives and the Figure 14 milling of a positive mould and illustrate the Figure 15 pieces of jewelry produced from a stamping mould operated by milling.

**Figure 12:** Deep milling of an aluminum mold.

**Figure 13:** Milling of a negative steel medallion mold.

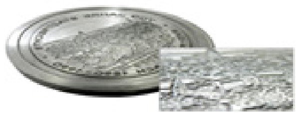

**Figure 14:** Milling of a positive mold.

**Figure 15:** Shows a piece of jewelry produced from a milling-operated molding.

Figure 16 is a milling application that does not require polishing, Figure 17 is an application for writing a product of a milling-operated mold, Figure 18 is a running of a positive milling mold and Figure 19 is a running of a negative milling mold (http://www.datron.com/applications/3d-engravings-stamps-dies.html). Figure 20 shows a set of jewelry items, composite rings, a chest clip for decoration and a ring for pocket watch and business that launches the field of imagination, design and innovation. Its complex three-dimensional wax models were prepared by machining with milling with four-axis JWX-30 machines. (http://www.rolanddga.com/products/milling/jwx30/).

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**Figure 16:** Milling application does not require polishing.

**Figure 17:** An application for writing a product from a milling-operated mold.

**Figure 18:** Operation of a positive milling mold.

**Figure 19:** Operating a negative milling mold.

**Figure 20:** A group of jewelry items whose wax models were prepared by engraving with milling.

## One of the most important advantages and limits of milling operation

Endurance, slow productivity, versatility, high efficiency and dynamism, ease in operating system (http://www.datron.com/products/cnc-machining/machine-overview/), non-large size machines that are easy to carry, desktop convenience and a rather non-fast worktop machining track, regular performance, automation, easy digital control, sufficient power for the rotational speed of the milling head (15,000rpm) to cover various works, maximum operating area of portable machines in inches 8 for the X x6 axis for the Yx2,5 axis for the Z axis, an example of which was the Roland EGX-20 desktop machining machine.

## The most important machines used in the process of operating products and jewelry by milling

Ronald EGX machining machines achieve accurate results, as their performance is qualified to process most products by machining such as appreciation awards, souvenirs, glass jewelry and guide signs. Figure 21 shows the EGX-20 machining machine with a competitive price and performance compared to its counterparts and with a fast surface scanner and software (http://www.rolanddga.com/products/engravers/egx20/). Figure 22 shows an EGX-30A desktop machining machine characterized by low cost, ease of use, suitable operating space 8x12inches and a package of machining and engraving tools and software (http://www.rolanddga.com/products/engravers/egx30a/). Figure 23 shows an MPX-90M desktop machining machine characterized by a rotational speed of the machining head above 20,000 revolutions/min, a suitable operating space of 9x12 inches, access to a high finishing surface, easy adjustments, machining tools, software and digital simulation options before operation (http://www.rolanddg.com/product/3d/udi/mpx-90m/index.html). Figure 24 shows the engraving machine for souvenir products with rotational shapes EGX-360 and is characterized by the milling of personal jewelry, rings and bands from the inside and outside, symbols and models made of metal, glass and flat and curved surfaces (http://www.rolanddga.com/products/engravers/egx360/). Figure 25 shows the portable machining machine XF500 Techni for workbench 100x120mm speed, compatibility, wide range innovation of accessories available (http://www.technifor.com/en/products/micro-percussion-machines/stand-alone-machines/xf500.html).

**Figure 21:** Ronald EGX-20 machining machine.

**Figure 22:** EGX-30A machining machine.


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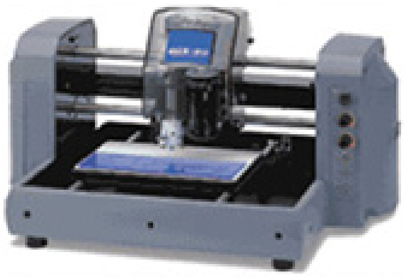

**Figure 23:** MPX-90M machining machine.


**Figure 24:** Engraving machine for souvenir products with flat and rotational shapes EGX-360.

**Figure 25:** Portable machining machine XF500.

Figure 26 shows the MDX-540 countertop milling machine that provides high accuracy, quality, fast and cheap parts and models and a digital driver that deals with a wide range of raw materials and occupies most of the parts starting from the functional and complex wax jewelry models that simulate finished products. Figure 27 shows the JWX-30 model milling machine, its program includes a jewelry design studio, professional computer manufacturing, removable and installable accessories, a high-speed milling tool with 30,000 tight rpm, high accuracy 0,00125mm/step, operating area in inches 12 for the X axis, 8,1 for the Y axis and 3,9 for the Z axis (http://www.jmrsys.com/pages/roland-JWX-10-mill.htm). Figure 28 shows an example of portable machines that perform milling and mechanical scanning together of the MDX-15 & MDX-20 model without accessories and they are easy to use and there is a digital counter surface to operate the wax blocks to be milled, acrylic or non-ferrous metals and the scanning technology depends on the sensor. Figure 29 shows the MDX-40A countertop milling machine operating system in 4 axes (milling tool and moving table), operating a variety of materials and providing a smooth surface finish, a suitable blade system and a maximum operating area in inches of 12 for the X axis, 12 for the Y axis and 4.1 for the Z axis and without a rotary table (http://www.rolanddga.com/products/milling/). Figure 30 shows a group of milling machines, Datron M75, ML1500, ML1600 and Inline (http://www.datron.com/products/cnc-machining/machine-overview/).

**Figure 26:** MDX-540 counter top milling machine.

**Figure 27:** JWX-30 milling molding machine.

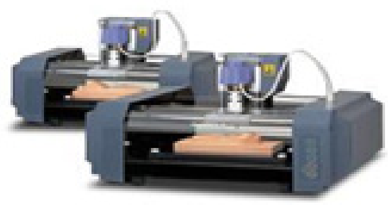

**Figure 28:** MDX-15 mechanical milling and scanning machine.

**Figure 29:** MDX-40A countertop milling machine.


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**Figure 30:** Shows a set of Datron machining machines M75, ML1500, ML1600 and line.

## 2- Laser Beam Engraving Machining

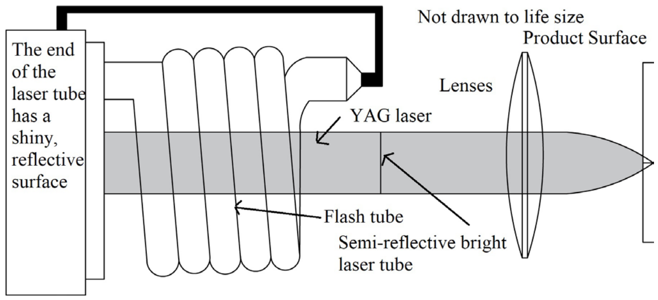


**Figure 31:** The idea of making YAG lasers that are used to etch the surfaces of jewelry and metal products.

The laser industry has developed rapidly and particularly effectively in the operation of product surfaces (http://www.bsu.edu./web/sambus). Laser machining is a thermoelectric heating model, which is used to evaporate layers of the surface of the metal to be operated. The word laser means a beam of light magnified by the activation of monochromatic emitted rays [7]. The laser converts electrical energy into a strong, coherent light beam based on the photoluminescence tube and has a high potential to generate temperatures of up to 75,000 °C instantaneously at the collection point [8]. The beam has a single wavelength and is parallel and non-dispersive, this makes the generated light concentrated in a very small focus only a few microns of millimeters per diameter to produce high strength densities and depending on the amount of energy of the beam of light that is graduated in its focus relative to the focus and performs different techniques [9]. The process begins with the generation of weakly powered flashes of light from a special valve and the flashing is amplified by a stalk of neodymium YAG crystal (yturium aluminium garnet) [8]. The YAG ions release photons whenever they hesitate in the crystal back and forth along it. The left end of the YAG leg is equipped with a 100% reflector, the right end is a partial reflector and the laser is based on the base shown in Figure 31, which shows a spiral tube that produces a strong flash of light after pumping the atoms from the YAG Laser to a higher energy level that is directed backward by reflection between the mirrors.

It is strongly amplified and red flashes out of the end of the silver part of the crystal at a critical point and is collected inside the work part. The self-amplifying state of the light wave inside the YAG leg remains until it is able to exit from the right side in the form of a strong light beam that can be concentrated to benefit from it in heating the surface of the product. The effectiveness of the beam release reaches its range whenever the cooling of the YAG leg. Nitrogen is used at a temperature of 180 °C whenever the flashing is worked in a hot atmosphere and the air is used to heat the flashing valve. The valve is isolated from the valve by a vacuum chamber and the frequency is clear between 3 and 12 °D [7]. The energy of the beam is concentrated not only instantaneously, but all the time and the beam become continuous or pulsating, producing energy in a burst of pulses against the surface. With the melting of the material, the surface can be evaporated at high speed. The general planning of the operation is shown in Figure 32. Laser engraving is a non-new but unconventional process. Energy is applied at a very small fraction to drill a fraction of the product surface, causing the fraction to be removed by the vaporization of work material [9]. Table 2 shows the basic operating factors in laser machining. The properties of the operated materials are their ability to absorb high light energy, poor reflectivity and good thermal conductivity and the product surfaces can be operated in carbon steel, stainless steel and jewelry surfaces in gold, silver, aluminum and copper alloys (http://www.netfirms.com).

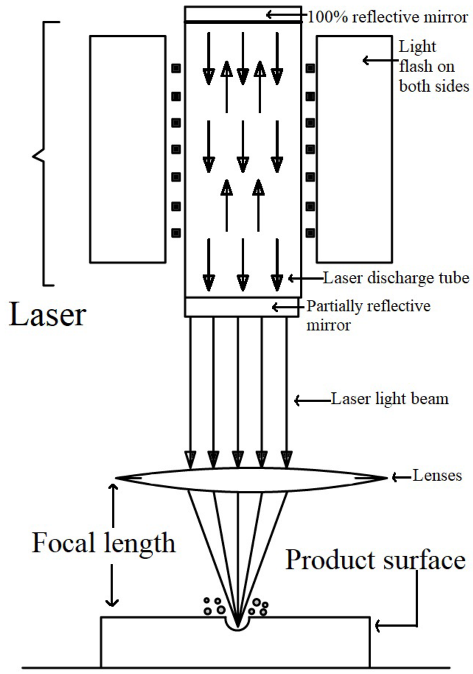


**Figure 32:** General planning for laser beam machining [9].


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**Table 2:** Shows a set of diverse factors that result in an unusual process [4].

| Basic Operating Power Fundamental Machining Energy | Remove from Work Piece Removal | Transfer Medium | Energy Source | Process of Elimination. Material Removal Process |
|---|---|---|---|---|
| Thermo-electric | Vaporization | Electrons | Amplified light | With laser technology laser beam machining |

The bundle passes above the surface and evaporates the material. The bundle path determines the shape to be engraved and takes into account two variables, namely the specifications of the surface material and the machining speed in addition to the power in watts [10]. The process begins with drawing the shape with the CAD programs and saving the file with the machine supplies such as dxf or dwg and sending it to the machine after converting it into its language to then adjust the operating factors and test the machining path without opening the laser. Figure 33 illustrates the use of lasers in machining plate surfaces. Machining occurs as a result of repetition of the pulse by focusing energy on the specified part of the material. It is possible to drill in specific places and areas with high performance and quality. The nature of machining technology programming allows high-speed applications. Hundreds of pieces are required in short operating cycles. In laser engraving, machining of bracelets, earrings, pendants, suspensions, medals and badges is carried out from brass. In laser numbering, contrasting lines and markings of shapes are implemented on the surfaces for ferrous and non-ferrous products. Figure 34 shows a set of applications whose surface is operated by laser engraving, respectively, between a picture, a symbol plate, a guide plate for the house from the outside and an identification plate with the name (http://www.troteclaser.com/en-US/Laser-Applications/Pages/Signage.aspx).

**Figure 33:** The use of laser systems in machining slabs (http://www.alspi.com/alt.htm#co2).


**Figure 34:** A group of applications whose surface is operated by laser machining.

Laser engraving is used in some areas of products and jewelry to engrave data and micro drawings on the inclined and rotational surfaces of products, engraving the surfaces of jewelry of precious metals and precious stones of diamond, agate and topaz. The excavation of monument roofs, appreciation awards, mobile device interfaces, seals, cups and key hangings and Figure 35 illustrate this (http://www.troteclaser.com/en-US/Laser-Applications/Pages/Awards-Trophies.aspx). Laser engraving of surfaces of rings, bands, pendants and bracelets as shown in Figure 36 (http://www.gravograph.us/engraving-machines/mechanical-engraving-m10jewel.php). Handle surfaces, mugs, utensils, souvenirs and tags of ionized aluminum (http://www.technifor.com). Machining can be applied to cylindrical, conical and spherical surfaces such as pots and cups through a rotating link unit to easily fix the models with a height of up to 400mm and a diameter of 1: 160mm as in the form of (37) with applications and the unit includes a horizontal inclination feature at an angle of up to 12° to allow additional uses (http://www.troteclaser.com). Gemstone surfaces can also be etched with a Co2 laser (Figure 37).

**Figure 35:** A group of products whose surface is operated by laser machining.


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**Figure 36:** A set of jewelry whose surface is operated by laser engraving (http://www.laserstar.net/jewelry/jewelry-laser-engraving.cfm).

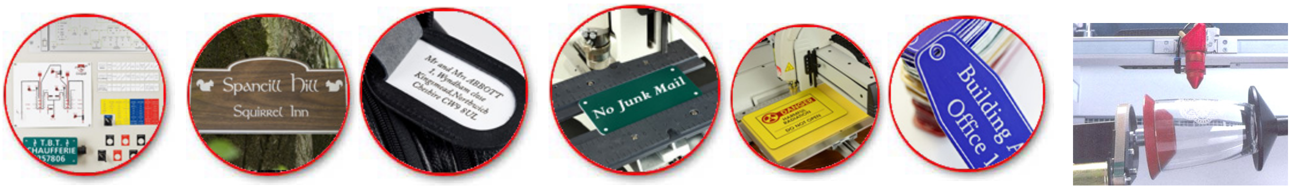


**Figure 37:** Rotating link unit that allows the machining of surfaces of rotational shaped models with applications (http://www.gravograph.us/laser-engraving-equipment/laser-engraving-machine-ls900xp.php).

## The most important advantages of laser engraving operation

Numbering the surfaces of hard, brittle and spandex metal products with high speed and quality. Acquiring sharp edges, more accurate details, ease of use, profitable, relying on it to produce the required quantity (http://www.troteclaser.com/en-US/Support/FAQs/Pages/How-to-Laser-Engrave.aspx). Application to delicate, small [11] and high-value precision parts such as jewelry surfaces, decorative tools and decorative products. Excavating sites from the surface by evaporating the material, the thickness of the evaporated layer is 0.002mm and this cannot be obtained by milling, any low-power laser can excavate an area of 1cm2 on the packaging materials with one pulse [12]. Laser machining is widely used because of its precise control of the concentrated and directed heat of the areas, where there is no distortion, no stress, no corrosion in the tool, no restrictions on the size of the drawings and innovative shapes and machining of inclined and curved surfaces [13,14].

## The most important machines used in laser machining

Laser machining machines are varied in terms of capacity, dimensions and working space and most are consistent in an air-cooled system [15-17]. Figure 38 shows some machining machines with a 60-watt YAG laser and next to it a beam guide tool that moves in the direction of X on a ruler that moves in the vertical direction Y on its vertical axis (http://www.ulsinc.com) [18-34].


**Figure 37:** Rotating link unit that allows the machining of surfaces of rotational shaped models with applications (http://www.gravograph.us/laser-engraving-equipment/laser-engraving-machine-ls900xp.php).

## Results

The study found that the advantages of laser machining are superior to the advantages of milling machining (Table 3).

**Table 3:**

| No. | Features | Milling Operation | Laser Engraving Operation |
|---|---|---|---|
| 1 | Mobile machinery | There are | None |
| 2 | Available technology | Engraving, deep engraving | Punctuation, surface excavation |
| 3 | Type of production per cycle | Only one piece - limited number | By piece, multiple, quantitative and infinite number, running numbers in one cycle and the quantity depends on the area of the product and the work surface [18,19]. |


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| | | | |
|---|---|---|---|
| 4 | Machinery | Less expensive | More expensive |
| 5 | Operational running cost | More expensive | Less expensive (economic) |
| 6 | Play Time: | Way higher. | - At least. |
| 7 | Operation space | Operation of limited and smaller spaces | Operation of varied and larger spaces. |
| 8 | Machine-available axle system | 5-axle | 6-axis |
| 9 | Operable materials | All materials such as gold, silver, copper, brass, aluminum, foam, wax, wood, plastic, acrylic, graphite and it is difficult to operate hard materials such as stainless and carbon steel and fragile materials such as glass and marble. | All materials such as gold, silver, copper, brass, aluminum, stainless and carbon steel, covered with zinc, glass, marble, wood, plastic, acrylic, foam and wax [20-22]. |
| 10 | Operating modes | Shapes, bodies, openings and contacts | Shapes, bodies and contacts |
| 11 | Rate of metal removal and perishability | Higher! | Min (0,003: 0,009%) |
| 12 | The surface finish and tolerances | Account needs review notification | No review needed |
| 13 | Use | In operating models more than product surfaces | In the operation of product surfaces more than models |
| 14 | Machine wiper type | Mechanic (adj.) | Laser |
| 15 | Forging mould | We need to set it up. | We don't need to prepare it |
| 16 | Operating maintenance cost | Min | Tops |
| 17 | Machinery | Strong! | Become more sensitive |
| 18 | Cooling system | Requires cooling of ethanol, oil, or air | No cooling required |
| 19 | Strengths required for machining | As high as possible | At least. |
| 20 | Impact of operation on the environment | Unhygienic | Clear |
| 21 | Surface condition after excavation | Doesn't need polishing | No post-excavation operations required |
| 22 | Speed, operating (Eng.) | Normal | Much higher, up to 4m/s |
| 23 | Play toolbar | There are | None |
| 24 | Shelf life of operating tools | Min | Tops |
| 25 | Installing the work-piece | required | Not required |
| 26 | Time, effort and money factor | Consumes | Provide |
| 27 | Fault reduction and industrial security | Min | Tops |
| 28 | Machining line rate width | Wider, please. | Tighter. |
| 29 | Dimensional accuracy | High | Higher than milling machining |
| 30 | Operating stress | It is not without them | It is devoid of them |
| 31 | Boring tool | Provided that it is stronger than the raw material of the operated product | It doesn't have to be stiffer |
| 32 | Actuator corrosion | Affects the efficiency or result of the operation. | Does not affect the efficiency or result of operation. |
| 33 | Surface machining Rate & Strengths | Depends on the hardness of the product material. | It does not depend on the hardness of the product material. |
| 34 | Material removed by Operation | Produced in contact with the product surface. | Produced without contact with the product surface. |
| 35 | The quality of the actuated shapes | Of | Simple and complex |
| 36 | Operation of composite, brittle and shell surfaces | Within | Unduly |
| 37 | Operation of high durability materials | Na | On hand |

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