Development of Low Cost Gemstone Polishing Cum Cutting Machine

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Abstract. Ethiopia has many types of natural resources that can be exported and brought high foreign currency; which can help to improve the financial status of this country. However; one of these resources is gemstone minerals, which is mostly preferred for jewelry purpose globally; due to its unique attraction, properties and natural behavior. Moreover; very expensive gemstone like opals, emerald, ruby, sapphire, etc. are available in this country in a huge quantity. However; these natural resources exported in raw form without post processing to the other developed countries to bring high foreign currency. Nevertheless; due the export presently we are not getting good returns on this export. By considering this fact gemstones processing jobs has been started in Amhara region of Ethiopia to add values and to increase the selling price of it. Hence present study focuses on the "Development of low cost Gemstone polishing cum cutting machine for further value addition of gemstone mineral. Mostly the available machines for gemstone processing globally are very expensive; therefore in the present study the efforts are taken to use the indigenous materials as alternatives to develop the low cost gemstone processing technology. This development work endorsed the dramatic cost reduction of the machine imported from abroad by saving more than 50% total cost.

Keywords: Gemstone · Cutting and polishing · Opal · Lapidary

1 Introduction

A gemstone or gem is a piece of attractive mineral, which is used to make jewelry or other adornments; when cut and polished. Mostly; gemstones are hard, but some soft minerals are used in Jewelry because of their luster or other physical properties that have aesthetic value. The most obvious and attractive feature of gemstones is their color. In general, stones like ruby, sapphire, emerald, and opal are gemstones where Amhara region (Particularly Delanta, Wegel Tena, Mezezo, Debre Brehan etc.) is known to have opal in ample quantity. Opal's mineral chemical name is hydrated silicon dioxide where the most essential feature of opal is its color, clarity and carat weight. The varieties of opal base color include chocolate, white, yellow, orange, dark red, root beer, and caramel [8]. There is a major shortages and importance of gemstone cutting and polishing machine over the years in Amhara region, Ethiopia in particular, and other parts of the country. Where the production of the gemstone jewelers normally takes place has necessitated the need to save foreign currency and modify upon the

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design of the machine. The most important of the components of the machine that can be modified and produced is coolant pumping mechanism. By doing so, there will be enhancement in the productivity, efficiency, ergonomics and safety of handling the machine in order to achieve its cost effectiveness and conducive and environmentally friendly conditions. These conditions will also attract the lapidaries who produce the jewelers for exportations and this will go a long way in contributing to the economy of the countries where large mining of gemstone takes place. Gemstone jewelers' production has been a target for small and large scale investors, and to follow the trend and encourage mass and qualitative production of the gemstone jewelries by trained lapidaries, there is the need to modify the design and manufacture of the existing gemstone cutting and polishing machine that will save high foreign currency. The developments steps of Gemstone polishing cum cutting machines were carried out as per engineering product development cycle [1–9]. As stated earlier, gemstone is used by the jewelry industry. Processed products of Ethiopian gemstones are mainly exported to Europe, America and Asia. In Ethiopia, there is a number of gemstone processing and exporting firms including Ethio-gemstone and Rift valley Gemstone although a complete list of firms engaged in the sector could not be documented [10]. The grading of Opal Gemstone is shown in Fig. 2(a–d).

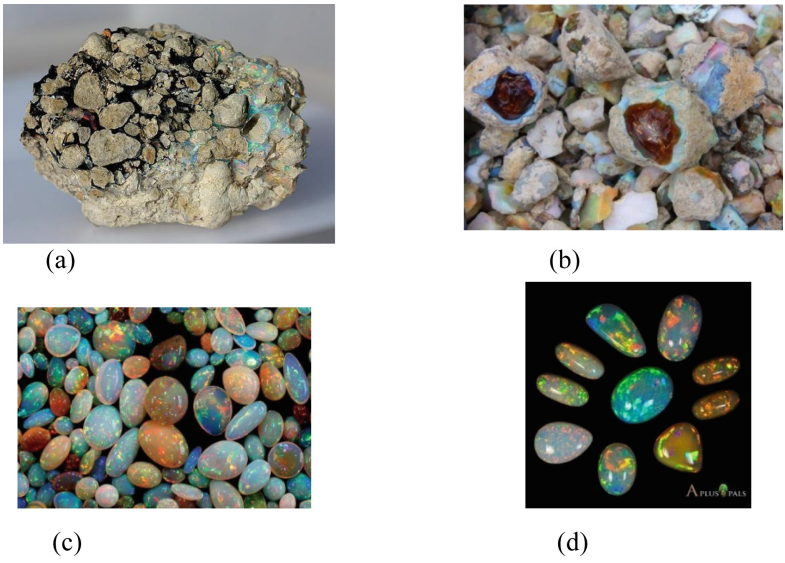

Fig. 1. (a): The opal typically fills spaces between pieces of volcanic rock debris, acting as cement. The black areas in this sample also consist of opal, together with Ba-Mn oxides. Photo by Mazzero [15]. (b) The carved wooden pick used by some of these miners to extract the rough opal at Wegel Tena. Photo by Mazzero [15]. (c) The carved wooden pick used by some of these miners to extract the rough opal at Wegel Tena. Photo by Mazzero [15]. (d) Rough opals before polishing [15]. (e) Rough opals before polishing [15].

(a) (b) (c)

Fig. 2. (a) Pixie gem maker machine, (b) Bigfoot gem maker machine (c) Genie gem maker

The process of cutting and polishing gems is called gem cutting or lapidary, while a person who cuts and polishes gems is called a gem cutter or a lapidary (sometimes lapidarist). Gemstone material that has not been extensively cut and polished is referred to generally as rough. Rough material that has been lightly hammered to knock off brittle, fractured material is said to have been cobbed [2–5] (Fig. 1).

All gems are cut and polished by progressive abrasion using finer and finer grits of harder substances. Diamond, the hardest naturally occurring substance, has a Mohs hardness of 10 and is used as an abrasive to cut and polish a wide variety of materials, including diamond itself. Silicon carbide, a manmade compound of silicon and carbon with a Mohs hardness of 9.5, is also widely used for cutting softer gemstones. Other compounds, such as cerium oxide, tin oxide, chromium oxide, and aluminum oxide, are frequently used in polishing gemstones [1] (Figs. 3 and 4).

Fig. 3. (a) Titan the biggest gem maker. (b) Sample price of imported gemstone trimming saw machine

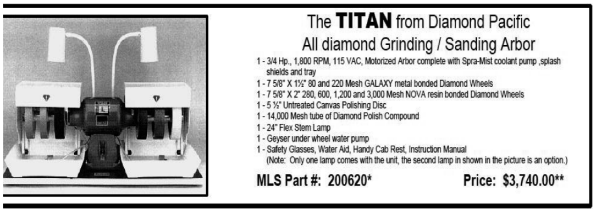

Fig. 4. Sample price of imported gemstone grinding machine.

The price of above machine is 3,740 dollar (about 63,580 birr) without considering the shipping cost. This price is very expensive to purchase the machine for Ethiopian graduate lapidaries; therefore it was decided to develop low cost polishing cum cutting machine to alleviate the problems and to save foreign currency [7].

2 Methodology

The "reverse engineering" methods was used to develop the product. Reverse engineering is a systematic approach for analyzing the design of existing devices or systems. Initial steps in the redesign process during reverse engineering process are: (1) Observe and assess the mechanisms that make the device work. (2) Dissect and study the inner workings of a mechanical device and (3) Compare the actual device to your observations and suggest improvements. Reverse engineering initiates the redesign process, wherein a product is observed, disassembled, analyzed, tested, "experienced", and documented in terms of its functionality, form, physical principles, manufacturability, and ability to be assembled. The intent of the reverse engineering process is to fully understand and represent the current instantiation of a product [10]. The primary objective of reverse engineering is the development of unrestricted technical data, adequate for competitive procurement, through engineering evaluations of existing hardware [15].

The process of the use of local and available materials in the near market and available machine in the near manufacturing area to fabricate the original imported machine which is less in cost and competitive in performance with imported machine is said to be indigenization.

2.1 Study and Value Engineering of the Imported Gemstone Cabbing Machine

The water pan, hood of the machine is manufactured from thermosetting plastics. The base of the machine is manufactured from laminated wood and Formica. It may absorb water and damage easily. It needs extra working table.

2.2 Selection of Materials for the Components of the Machine

The criteria for material selection of the materials for the various components of the machine is based on the type of force that will be acting on them, the work they are expected to perform, the environmental condition in which they will function, their useful physical and mechanical properties, the cost and their availability in the local market or the environment [11]. Since our task is reverse engineering and indigenization of the imported gemstone machine, materials for each component is selected by using experiences familiarities and know ledges with the available materials of properties, fabrication methods, functional requirements, cost and others. After studying and knowing the nature and functional requirement of indigenous engineering materials, the following materials are selected for the basic components of the machine. The most critical machine elements that need design analysis in the reversed gem stone

cabbing machine are shaft, pulley, belt, bearing and air pump [12–14]. The material used for the designed components of polishing cum cutting machine for gemstone is as given below in Table 1.

Table 1. Selected materials for the components of the machine

S n	Machine part	Selected materials	Selection criteria
1	Shaft	Medium carbon steel	Easy machinability, local availability cheap in cost relatively and its strength
2	Pulley	Aluminum	Material selected is aluminum since it is deep affordable, resistant to heat and wear, light in weight, and easily machineable
3	Nut	Aluminum	
4	Spacer	Aluminum	Material selected is aluminum since it is cheap and affordable, light in weight resistant to heat and wear, and easily machineable
5	Machine bodies (table, hood bowel and others)	Carbon steel (C20)	Cheap, affordable, easy fabrication and is of high carrying capacity
6	Eccentric circular CAM Piston (follower)	Medium carbon steel	Strength, wear resistant and easy fabrication
7	Piston housing	Medium carbon steel	Strength, wear resistant and easy fabrication
8	Piston housing	Medium carbon steel	Strength, wear resistant and easy Fabrication
9	Air pump top and bottom covers	Aluminum	Material selected is aluminum since it is cheap and affordable, light in weight and easily machineable

3 Results and Discussion

The designed prototype Gemstone polishing cum cutting machine by using reverse engineering techniques is presented in Fig. 5.

Figure 5 present the exploded drawing of gemstone cutting cum polishing machine, the various designed components of Gemstone polishing cum cutting machine are briefly described as follows.

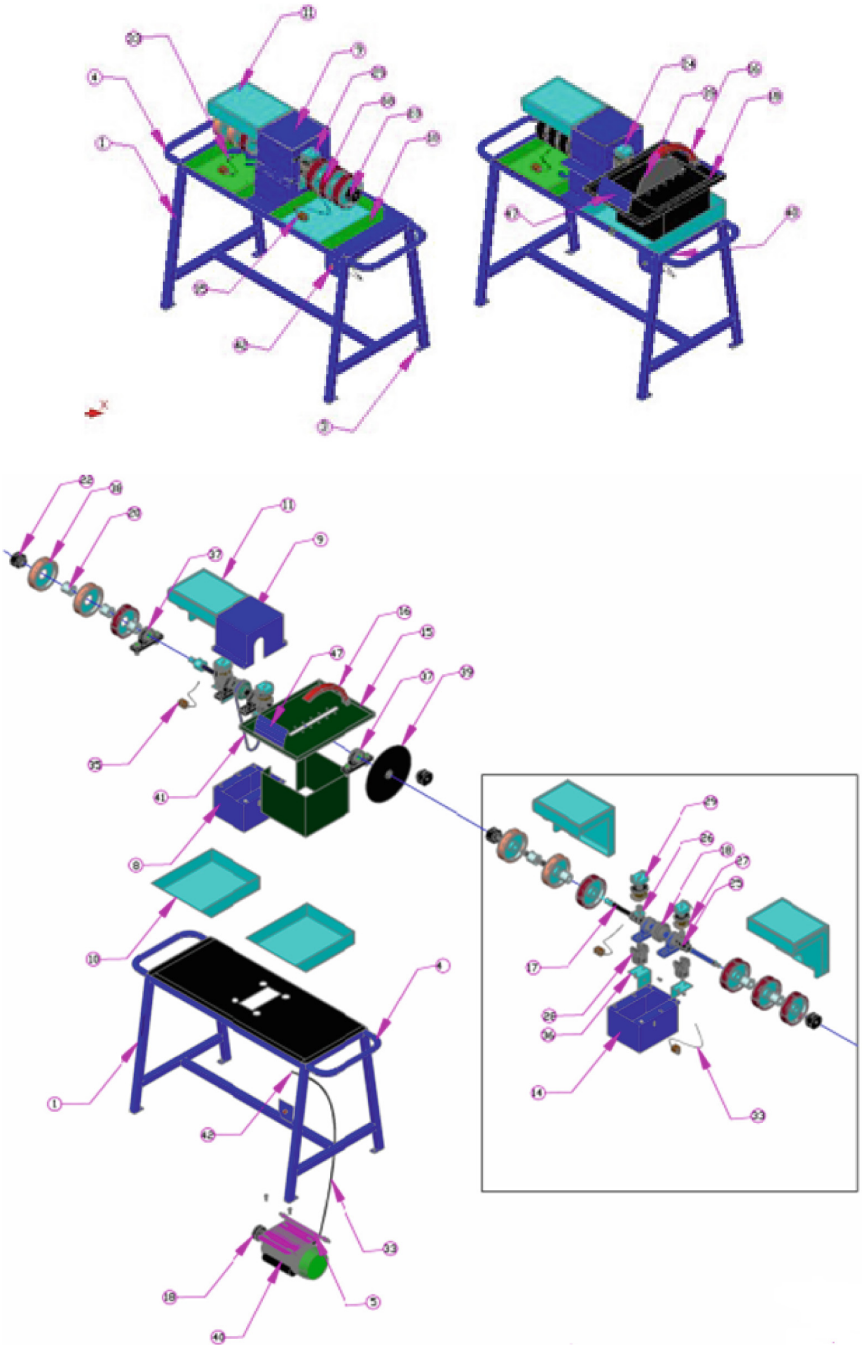

Fig. 5. Parts of the designed gemstone polishing cum cutting machine

1. **Machine base**
   The base is one of the main components of the Gemstone polishing cum cutting machine, which holds switch holder, belt guard and motor seat. It is used to support all components of the machine. The base is fabricated from SHS (square hollow steel 30 mm × 30 mm × 2 mm) and black sheet iron = 3 mm thickness. The SHS is cut to legs and rails to size as specified in the working drawing and assembled with welding. The base foot is prepared from flat iron 30 mm width × 2 mm thickness × 60 mm length and at one end 10 mm hole should be drilled to fix the machine on the floor and welded at the foot of SHS. The top part of the frame is assembled with black sheet iron (1000 mm × 400 mm × 3 mm), which is notched at the center to pass the belt towards to motor, by applying intermittent welding.
   The round tube which has 30 mm diameter is bent at the specified profile and weld to the frame that helps to move the machine from place to place. The switch holder is fabricated from black sheet iron (80 mm × 80 mm × 2 mm) which is drilled at center with 16 mm drill bit and welded at the right top corner of the base to hold the machine switch. The tool kit, motor seat and belt guard are fabricated separately and fixed with the frame by temporary fasteners like bolts and screws.
2. **Shaft and bearing seat**
   This part has a shape of rectangular box after welding of its component together and fabricated from 6 mm thickness of plate (200 mm × 240 mm × 150 mm). The bottom part has four holes which is drilled with 12 mm diameter of drill bit that helps to fix with the base of the machine as shown in the working drawing. Similarly the top part has four holes of diameter 12 mm to fix the bearing on it. It is used to support the bearing and all assemblies of the shaft. Each components of the part can be cut by hydraulic shear or cutter disc and assembled with welding by keeping the straightness and perpendicularity of the part.
3. **Bearing cover of the machine**
   Bearing cover is used to cover bearings and the driven pulley at the top of the machine. It is fabricated from black sheet iron of 2 mm thickness by shearing, bending and welding process as indicated on the working drawing and SHS (10 mm × 10 mm × 1 mm) is cut and welded at the top edges of the cover to support and hold trimmed gemstones temporarily.
4. **Water pan (bowel) of the machine**
   The bowel is fabricated from black sheet iron of 3 mm thickness which has the pattern development size of (445 mm × 420 mm × 3 mm). After laying out of the pattern, holes are drilled with 7 mm drill bit at the back that helps to fix the hood on it. And the lay out line is grooved with cutter disc to minimize bending strength and then bending and welding operation is followed.
5. **Hood (wheel cover) of the machine**
   The hood is fabricated from black sheet iron of 2 mm thickness, flat iron (30 mm × 2 mm) and SHS (10 mm × 10 mm × 1 mm). First the sheet metal is cut in size and bends to the required shape and the flat iron is cut, drill and weld as the specified dimension and again assembled with the bent sheet metal. Finally the SHS is cut in size and weld at the top edges of the hood to hold gemstones temporarily during cutting and grinding process and a plastic mirror is cut to the

desired shape by band saw and assembled at the left and right side of the hood for safety and to observe the rotation condition.

6. **Trim saw body**
   The trim saw body is an assembly of stand, trimming table and blade guard. This body is attached to the bowel with screw temporarily during trimming operations. After trimming enough pieces of gemstone the attachment is disassembled and substitute grinding wheels with trim saw blade. The stand and the table is fabricated from 3 mm of black sheet iron by cutting and bending operations. The table has a long slot to run the trim saw blade which is slotted by cutter grinding disc. The curved blade guard is fixed with screw at the back edge of the table.
7. **Shaft of the machine**
   This shaft is fabricated from mild steel of 0.26% carbon content (BS07m26). The actual length of the shaft is 750 mm with stepped profile. But for machining process, 40 mm diameter of steel which has 800 mm length is cut. First of all, the cutting tool and lathe machine should be set up as required. Then steady rest or follower rest should be attached to the lathe bed to support the shaft during machine operation. At the first time the shaft end should be faced accurately and center drilling should be followed to support one end with revolving (live) center. Each section of the shaft should be turned to the specified dimension and allowable tolerance. Produce fine series left and right v-form thread at 16 mm diameter and finish the trim saw blade place. Consequently, cut the required size of the shaft using parting tool and go to cylindrical grinding machine to bring the specified dimension and surface finish. Finally drill a hole on the shaft for pulley and eccentric cam assembling with 5 mm drill bit and produce a v-form thread by using M6x1 thread tap.
8. **Pulley of the machine**
   The two pulleys are fabricated from aluminum materials with the calculated diameters, groove angles and other parameters. It is used to transmit power from one section to the work section.
9. **Spacer of the machine**
   Spacers are fabricated from aluminum ingot and it is used to guide and space the grinding wheel on the shaft.
10. **Nuts of the machine**
    Nuts are fabricated from aluminum ingot and are used to tight and guide the grinding wheel on the shaft.
11. **Air pump of the machine**
    Air pump is an assembly of eccentric cam, piston, piston housing, check valves and cover with seal. It is used to suck air from the surrounding with inlet check valve and the compressed air is displaced to the hose by out let check valve with high pressure to spread water from the bowel through the gather to the grinding wheel.
12. **Painting of the machine**
    To prevent surface corrosion and for aesthetic purposes, first of all the surface of the component of the machine should be polished with wire cup to remove corrosion and other dusts. It is also filled by metal body filler if deformed or irregular surface is observed and is polished by fine sand paper (No. 80, No. 120) to make the surface leveled and smooth. Finally the parts should be painted with antirust by

using compressor and consequently, it should be painted with the user desire color repeatedly until getting uniform feature and beauty.

4 Conclusions

The reversed gemstone machine is fabricated from indigenous materials by considering scientific engineering principles and manufacturing processes. This machine is a combination of trim saw and cabbing machine. Therefore it can be used to trim and polish gemstones by exchanging the trim saw blade and gemstone grinding wheels. The critical parts of this machine (shaft, pulley, belt, bearing, pump etc.) are analyzed to ensure the functionality of the machine as expected. The reversed gemstone cabbing machine is manufactured cost effectively which reduces about 60% of the existing machine cost and any lapidarist can afford 26,261.75 birr to buy and to use easily.

Generally, the reversed gemstone cabbing machine are analyzed and manufactured by following the reverse engineering principle and procedures to make it robust, long service life, efficient and effective, cost effective, ergonomically convenient and environment friendly. The reverse engineering and manufacturing of this machine is to provide significant of it manufacturing for, to solve the problem stated in these literature as a whole and to attain the objectives stated.

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