Design for Manufacture and Assembly of an Automated Mirror Cutting Machine

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Abstract

The research paper is based on the design of an automated mirror cutting machine for a developing country in a low level production system. Current machines are very expensive. Research on types of mirrors and car manufacturing industries was conducted on the internet, and also industrial visits to local car manufacturing industries. Firstly the experiment was conducted in the lab and the force F=2.7kN required to break the mirror was found, this force was used to calculate the deflection y=39.44mm and bending stress$= 305.5N/mm^2$. In the design process a cylinder of internal diameter d=75mm and a solenoid valve with flow factor $C_v = 1.5$ were selected. The maximum von Mises in each of the tested components were below the yield stresses of the respective components hence this machine will not fail under normal operations. The maximum von Mises stress= $2.948MPa$ for the cutting wheel is less than the design stress= $18.387MPa$, therefore the design is safe. In this project an Arduino board will be able to read the input (pressure) by the use of the pressure sensors and turn it into the output, when the pressure from the compressor is great than 10.5bar the red LED light will be turned ON, then the operator of the machine will witch it OFF. Above all the operator of this automated machine should be well skilled and wear goggles during the operation of the machine. An automated mirror cutting machine was designed within a budget of USD$4 221.34 and the machine can cut mirrors ranging from 20mm*20mm up to 500mm*500mm as stated from the objectives.

Keywords
Design, pneumatically powered, mobile, Zimbabwe

1. Introduction

Present automated mirror cutting machines are very expensive and therefore are not affordable by the local car industry, therefore the aim of the project is to design an automated mirror cutting machine for local car manufacturing industry. The objectives of this research are as follows: to design a machine that can run automatically which essentially tracks the direction of the target, to design a highly automated machine that cuts any shape of mirror, to design a machine that cuts mirrors ranging from 20mm*20mm up to 500mm*500mm.

2. Materials and methods

Possible solutions were generated and best solution was chosen.

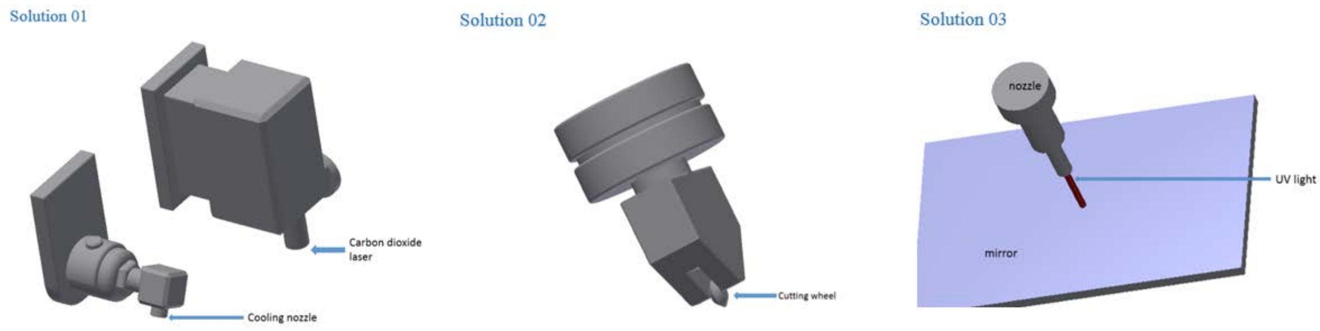


Figure 1. Concept generation

Solution 01: Focused laser beam heats up a specific line on the mirror, followed by a cold jet of air / liquid mixture from cooling nozzle. This thermally induced tension causes precise fissuring of mirror.

Solution 02: A cutting wheel, made of tungsten carbide or polycrystalline diamond and with a V -shaped profile, is pressed firmly against the surface of the mirror and a line is briskly scribed to form a "score" or "cut". The mirror is now weakened along the scribe line and the mirror sheet is ready to be "broken" in two.

Solution 03: This method is used in cutting out shapes inside the mirror using Ultraviolent Light (UL) laser without destroying it. After performing the Binary Dominance Matrix, concept 2 become the best solution

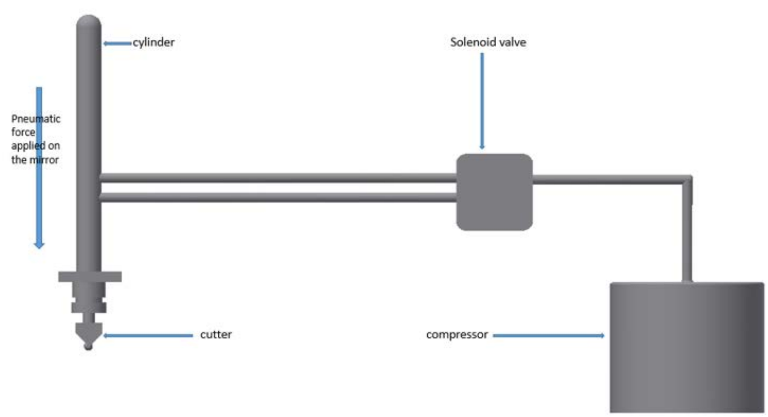


Figure 2. Chosen solution

Compressor supply compressed air, this is passed through the solenoid valve with only one input. The solenoid valve has two outputs. The cylinder controls the up and down movement of the cutting tool. The lateral movement of the tool is controlled by means of servomechanism programmed using fuzzy logic. Mirror to be cut is placed on a table by means of a robotics.

2.1 Experiment

An experiment was carried out to determine the force after calculations it was shown that a mirror of 1.6mm thickness will require a force of 2.7kN in order to break. This force is the one that was used by the designer in the sizing of cylinder and compressor. Pressing experiment using Tensometer was done. The relationship between applied forces and motion of the cutting wheel is counter-intuitive and so needs careful explanation. The researcher provide an experiment to show the force that is required to break a view mirror by applying a force using a presser.

Figure 3. Experiment done in the laboratory

- Side view mirror
- Hounsfield Tensometer
- Presser
- Vernier callipers

The experiment was repeated for several time and the average force required to break the mirror was calculated as shown in Table 1.

Table 1. Set of results after the experiment

F_1	**2.8KN**
F_2	2.5KN
F_3	2.9KN
F_4	2.5KN
$F_{average}$	2.7KN

Thickness of the mirror used=1.6mm

Diameter of the presser=2.1mm

2.2 Software's and Drawings

INVENTOR 2014 Software was used for the 3D modelling of the design and its various components. Stress analysis to assess the safety of the design on pressure in pipes was carried out using Inventor 2014 software. AutoCAD software was used during to generate 2D drawings. Mat lab R2015a software was used for vibrational analysis, for performing complex calculations for optimum machine design. Arduino 1.6.5 was used to programme the machine such that when the pressure is above 10.5bars the red LED will light ON. Machine was designed the following specifications.

3. Results and Discussion

Area of the presser $A = \pi r^2$

$$= \pi * 1.05^2$$

$$= 3.46mm^2$$

Therefore the pressure required $p = \frac{F}{A}$

$$= \frac{2.7 * 10^3}{3.46 * 10^{-6}}$$

$$= 2.39 * 10^{10} Nm^{-2}$$

$$= 23900MPa$$

Table 2. Machine specification

Machine width	**1500mm**
Height	1000mm
Length	2000mm
Weight	1000kg
Cutting efficiency	30-60mm/min
Min cutting size	20x20mm
max cutting size	1000x1500mm
working area	1200x1700mm

3.1 Summary of the calculations

Bending moments: Deflection y=39.44mm

Design of a cylinder: Calculated diameter of the cylinder d=72.9mm. For the design to be safe, the designer have taken a cylinder of internal diameter d =75mm, it is 174mm long and 2.5mm thickness

Selection of the solenoid valve: C_v=Flow factor=0.58

Designing of a pneumatic actuator: Bending stress induced $= 305.5N/mm^2$. Angular deflection of the spring (in radians) $= 28^0$.

Designing of a bearing: Power lost during friction$= 14.27kW$. Heat generated at the bearing $= 856.2$KJ/min

The dimensions of cutting wheel are shown in Table 3.

Table 3. Cutting wheel

	Thickness (t)	**Wheel angle (v)**
Diamond pin/wheel	50-200μm	105^0 or 110^0
Diamond wheel	200 μm	110^0
Diamond wheel	400 μm	110^0 or 115^0
Carbide wheel	600 μm	115^0 or 120^0

3.1.1 Von misses stress

The von Mises stress analysis were carried out and it shows that the maximum von Mises in each of the tested components were below the yield stresses of the respective components. This components will not fail under normal operations.

3.1.2 Machine drawings

The machine drawings were drawn out and will be used to manufacture and fabricate the individual components. The components will be assembled to come up with a single unit as it appears on the working diagrams as shown in Appendix 1.

Control aspect

The control aspect is the brains behind control system. As long as a system can be explicitly defined it can run under automatic control. The controller accepts the error signal and generate an output signal in order to drive the machine to a desired state. In this design the controller is working in conjunction with the pneumatic construction in order to execute some very simple algorithms. In this case the controller generates a commands to the system such that the output continuously tracks that input. The input (mirror sizes and shapes) could in principle change frequently and randomly and the output (cutting tool) is expected to match it. The PLC was selected among other controllers because it require less wiring, easy to program and easy to trouble shoot.

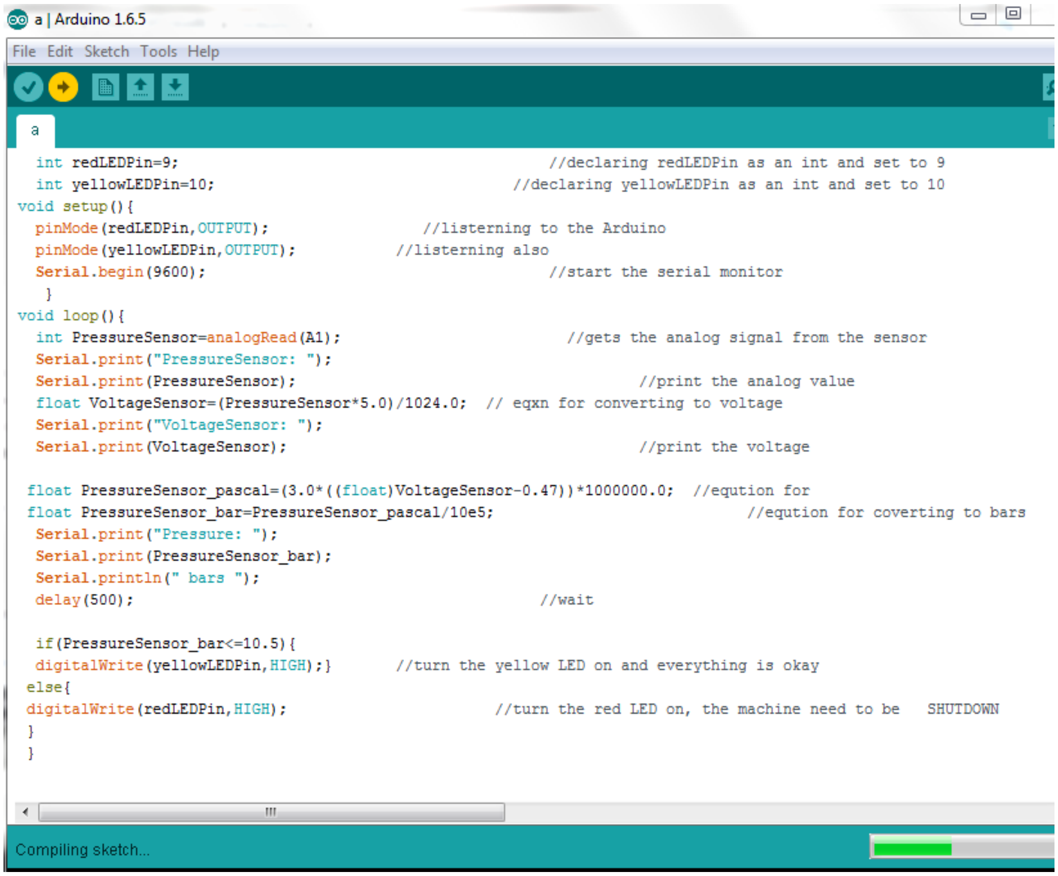
Selection of sensors depend upon its application and there two main categories which are proprioceptors and exeteroceptors. A sensor is a device that respond to the input from the environment, thus converting the physical variable into an electrical signal and this signal is in digital form so that it will be evaluated by a computer. In this machine the variables of interest are pressure, temperature and speed. An arduino is an electronic platform that connects or interact the hardware and software of the machine. In this project the Arduino board will be able to read the input (pressure) by the use of the pressure sensors and turn it into the output, when the pressure from the compressor is great that 10.5bar the red LED light will be turned ON.

It is an electronic platform that connects or interact the hardware and software of the machine. In this paper the Arduino board will be able to read the input (pressure) by the use of the pressure sensors and turn it into the output, when the pressure from the compressor is great that 10.5bar the red LED light will be turned ON. The operator of the machine will witch it OFF. The blue colour at the right bottom corner shows that the code is compiling.

4. Recommendation

The operator should make sure that he/she understand all the processes before operating the machine. During the operation of the mirror cutting machine, a lot of small glasses or mirrors fall to the ground and all over around the machine. To maintain a clean and a safe environment it is basically recommended that a small mirror removal system which uses a vacuum pump and pneumatics should be used to suck all the small mirrors and this pump should be installed on a mirror cutting machine. An automated mirror cutting machine has moving members and sharp objects and this will may injure the operator of the cutting machine or person around that machine. It is recommended that any person should practice proper behaviour when that person is closer to that machine to avoid any injuries. Electrical drives in a mirror cutting machine are high voltage devices. It is mainly recommended that this devices should be earthed and to check all the wiring from time to time. The operator of the machine should wear goggles all the time when he/she is operating that machine. This will prevent fine glasses from entering the eye of the operator. The emergency stop button should be functional all the time. It should be red in colour for easy recognition and should be at a position that can be easily reached by the operator or any person around the mirror cutting machine.

3.2 Arduino




```
  int redLEDPin=9;                                    //declaring redLEDPin as an int and set to 9
  int yellowLEDPin=10;                            //declaring yellowLEDPin as an int and set to 10
void setup(){
  pinMode(redLEDPin,OUTPUT);                 //listerning to the Arduino
  pinMode(yellowLEDPin,OUTPUT);            //listerning also
  Serial.begin(9600);                                  //start the serial monitor
   }
void loop(){
  int PressureSensor=analogRead(A1);                     //gets the analog signal from the sensor
  Serial.print("PressureSensor: ");
  Serial.print(PressureSensor);                                    //print the analog value
  float VoltageSensor=(PressureSensor*5.0)/1024.0;  // eqxn for converting to voltage
  Serial.print("VoltageSensor: ");
  Serial.print(VoltageSensor);                                     //print the voltage

 float PressureSensor_pascal=(3.0*((float)VoltageSensor-0.47))*1000000.0;  //eqution for
 float PressureSensor_bar=PressureSensor_pascal/10e5;                          //eqution for coverting to bars
  Serial.print("Pressure: ");
  Serial.print(PressureSensor_bar);
  Serial.println(" bars ");
  delay(500);                                        //wait

  if(PressureSensor_bar<=10.5){
  digitalWrite(yellowLEDPin,HIGH);}       //turn the yellow LED on and everything is okay
 else{
 digitalWrite(redLEDPin,HIGH);                    //turn the red LED on, the machine need to be   SHUTDOWN
 }
 }
```

Figure 4. Arduino code

5. Conclusion

The paper was successfully done. An automated mirror cutting machine was designed within a budget of USD 4 221.34 and the machine can cut mirrors ranging from 20*20mm up to 500*500mm as stated from the objectives. The machine can also cut any shape of mirror. In the designing of the machine local materials were used so as to promote local companies by keeping the cost as minimum as possible and maintaining the quality. Improving a robot will help in increasing the accuracy and precision. A robot has an advantage over humans because it does not require sick leave and it does not affected by fatigue.

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Biographies

Allen Hondo is a University of Zimbabwe Graduate in the department of Mechanicla Engineering. Her current research involves Robotics, Dynamics, Solid Mechanics and Finite Element Analysis.

Dr. Tawanda Mushiri received his Bachelor of Science Honors Degree in Mechanical Engineering (2004-2008) and a Masters (2011-2012) from the University of Zimbabwe, Harare, and a Ph.D. from the University of Johannesburg, South Africa (2013-2017). He also obtained a Certificate with Siemens in Programmable Logic Controllers in the year 2013 where he worked with SCADA and Link Programming. His doctorate involved fuzzy logic and automated machinery monitoring and control. Currently, he is a lecturer and Senior Research Associate at the university of Zimbabwe and University of Johannesburg, respectively. In the past (2012-2013), he has also lectured at the Chinhoyi University of Technology, Zimbabwe, lecturing mechatronics courses. He has also been an assistant lecturer for undergraduate students at Chinhoyi University of Technology, tutoring advanced manufacturing technology and machine mechanisms.

Professor Charles Mbohwa is an NRF-rated established researcher and professor in the field of sustainability engineering and energy focusing on green technology, energy and systems. In January 2012 he was confirmed as an established researcher making significant contribution to the developing fields of sustainability and life cycle assessment. He has contributed a chapter to a state-of-the-art book by experts in energy efficiency. In addition he has produced high quality body of research work on Southern Africa. Since 2012 he has worked on sustainability engineering with emphasis on integration of other soft aspects like humanitarian logistics and health care systems. The work also encompasses and integrates energy systems, life cycle assessment and bio-energy/fuel feasibility and renewable energy.

Appendix 1: Detailed drawing of the mirror cutting machine.