Conceptual Design and Modeling of Mechanically Operated Carpenter's Nail Gun

Ahmed Mohammed Adem
School of Mechanical Engineering
Jimma institute of Technology, JiT,
Jimma, Ethiopia

Abstract: **This paper focused on mechanically operated carpenters nail gun. It has generally considered replacing traditionally carpenters hammer by semi-modern carpenters nail gun to reduce fatigue of Ethiopian carpenters. In each stage material selection is done for individual component. The effectiveness of human power checked with an experiment with leading by ergonomically data. The experiment is held on local materials by using balancing weight, locally existed wood, hammer and different types of nail in order to check the amount of output force, 300Newtons resulted by analytical method is sufficient or not. According to test this carpenter nail gun is functioning on wood workshops for thickness of 25millimetre - 35 millimeter pair of wood, by 50 millimeter -70 millimeter nail length. According to the result each types of nail size have different force to penetrate the bond between the elements, because of difference in width of nail.**

Keywords: - Carpenter's nail gun, Nail, Wood, spring, Gear

1. INTRODUCTION

In our country, traditionally carpenters are used hammers to join woods. Hammers are an energy consumed tools, in addition to this, to insert the nail in to the wood it need a perfect target, otherwise the nail may be deflect in to the operator or it may be bended, The working conditions of the carpenters are not conformable and it is tiresome. In order to join two woods, they should be hit up to on average up to ten times for a single nail. But this joining technique is energy consuming method.

Stud guns have become an indispensable tool in modern building construction and maintenance.

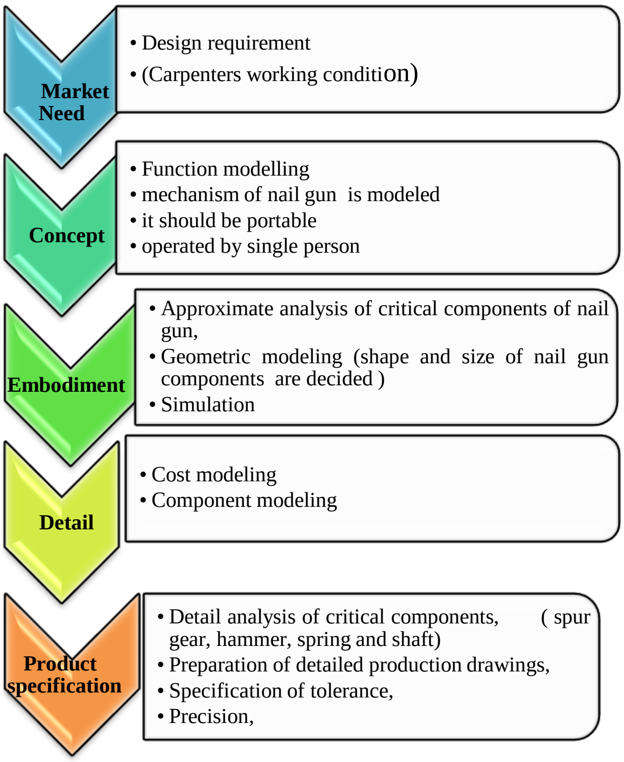
They are used to attach materials like woods, steel, and concretes. They were first introduced in the early 1950s; now, perhaps as many as a hundred may be found at a single construction site. This device is known by many names, such as powder-actuated tool, explosive-actuated fastening tool, nail gun, masonry gun etc.

This tool uses as an energy medium like compressed air, compressed inert gas, internal combustion and also an electric power for actuating nails well. When it used to deliver force it may be damage body tissue, to minimize this sever accidents proper standards and recommended work practices are must be followed.

Generally modern technology with its accompanying labor-saving devices are seldom which is free from potential hazards. So we must substitute mechanically powered carpenter's nail gun instead of traditional carpenter's hammer.

1.1. THE DESIGN PROCESS

Design is an iterative process. The starting point is a market need captured in a set of design requirements. Concepts for a product that meet the need are devised. The design proceeds to the embodiment stage: working principles are selected, size and layout are decided, and initial estimates of performance and cost are made. If the outcome is successful, then we proceeds to the detailed design stage: full analysis of critical components, preparation of detailed production drawings, and specification of tolerance, precision, and so forth.



FigureI.Design flow chart,

Materials selection enters each stage of the design. The nature of the data needed in the early stages differs greatly in its level of precision and breadth from that needed later on (Figure I).

1.2. Test on Wood Hardness with Different Nail Size

In the designing process the force to penetrate bond between wood particles is required. For this reason, it is recommended to refer available data with related to mechanical properties of wood specious. But, most of the available data is, wood specious that are not usually used in our country, because of

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this, an experiment is needed to be conducted. The experiment is conducted by using oscillating weight balance, hand pressing machine and different types of nail size.

To conduct this experiment some considerations are made;

- The wood specious *Cordiana Africana* (wanza) is selected
- The strength or hardness of the wood is depending on the content of water, hence the content of the water of the wood is assumed equally distributed,
- Significant change will be appear when there is change on,
- Specific gravity of the wood and
- Diameter of nails
- The considered wood type is free from knot,
- The joining surface of the two woods is in the radial direction.

Hence our aim is to insert the indicated nail in to the pair of wood. Force is applied on the nail gradually, because it is difficult to record the digits during impact load. Recording is taken after penetrating of the wood when the nail is start going down.

According to the result each types of nail size have different energy requirement to penetrate the bond between the elements, because of difference in width of nail.

For *Dia.2.09x44mm length of nails, need 20kg or 196.20N*
Dia.2.40x50mm length of nails, need 27kg or 266.30N
Dia.2.87x57mm length of nails, need 30kg or 294.30N
force is applied.

From the experiment result *the maximum force required to penetrate the bond between wood particles is 295N force*. The aim is to *design mechanically operated carpenter nail gun that can produce greater than or equal to 295N force*.

1.3. Mechanism and Operating Principle of Nail gun

Mechanically operated carpenters nail gun is powered with compressed spring; the compression force is done by mechanically meshing spur gear and rack gear, with including buttress thread, in order to fire nails there are slightly small procedures.

Once the nail is available in the magazine, the operator is pull rotationally to compress the spring, when the handle is rotate, arm and shaft is also rotates with the handle. To create one directional motion and force application we use buttress thread. When compression spring is reached at ultimate compression limit, we just loose our hand, to make it free from force applying. So the spring is pushing the hammer.

When the handle is pull backward the force is transmit in to the arm length that rotate shaft and then into the spur gear with the help of ratchet and pawl mechanism the rack will compresses the spring. When the spring is fully compressed it is released quickly by press the trigger at this time the hammer is driving into the nail. The spring returns to its neutral position, ready to be compressed for the next nail.

Pre-conditions

i. The nails are available in the magazine; the capacity of the magazine is about 15 nails.
ii. The operator is being held the fixed holding with the right hand.

The benefits of the new mechanically powered carpenters nail gun available in the market, even if it is not available in Ethiopia,

- Reduce the designed total product cost
- Reduce number of components from 100 to 20
- Change working principle mechanism from complex to simple (from explosive, electrical, and compressed air in to mechanical)

1.4. Design for Manufacturing

In the design of mechanically powered carpenters nail gun the mechanism starts at the handle powered by the working man. Ergonomically literatures indicate that “one person can apply 196.4N force in case of radial motion continuously for 8 hours” [10]. It is assumed that for safety reason at the handle 60N force is exerted, this force is transmitted in to the spur gear with the_help of arm length through shaft and then in to the rack. The rack compress the spring, at this stage the power is induced in to the spring, when the stopper is removed the spring push off the rack, then the rack that is connected with the hammer exerts a force into the head of the nail then the nail will penetrate the woods and join them.

The moment of a force, or torque, is a measure of the force's tendency to cause rotation. It is defined as the product of the magnitude of the force and the perpendicular distance from the axis of rotation to the line of action of the force. In Figure 1, the moment of force, F about an axis of rotation through moment arm is given by F x d. (Of course, the units of torque are those of force distance).

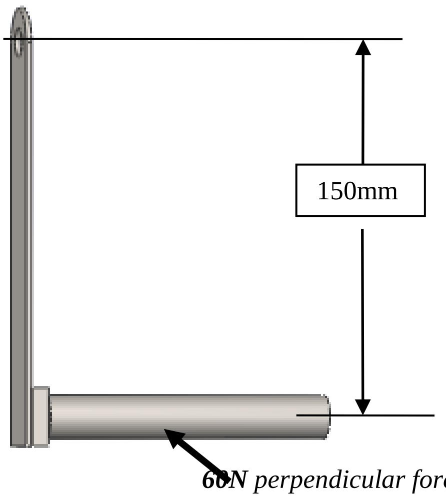

Figure II the handle and moment of arm

Given: - r=150mm=0.15m and F=60N

Torque the at the handle is become

T = F × r ,T = 60Nx150 then T = 9000 = 9kN

Hence these amounts of torques develop at the conjunction of the shaft and the arm length. The indicated torque is crate a force between at the conjunction of the arm and the gear.

1.5. Design of Shaft

The shafts may be designed on the basis of

- Strength, and
- Rigidity and stiffness.

In this case the shaft is subjected to twisting moment or torque only; we only consider Shafts Subjected to Twisting Moment Only

When the shaft is subjected to a twisting moment (or torque) only, the diameter of the shaft may be obtained by using the torsion equation.

Where d=diameter of the shaft or diameter of the hole in the hub. By taking safety factor of 2, $d = 2 \times 7.1 = 14.2 \sim 15mm$.

Design of Spur Gear

Gear having straight teeth cut on the rim, parallel to the axis of rotation. Most common and cost-effective type of gear, designed to transmit motion and power between parallel shafts which rotates in the opposite direction. The 20-degree PA gear tooth forms have wider bases and can transmit greater loads. 20-degree PA tooth forms will not mesh with14.5-degree PA teeth. Be certain to verify the Pressure angle of the gear is use.

Pressure angle=20^o and Module of the gear is 2.5

Diametric Pitch (D_P)= $m \times N = 2.5 \times 24 = 60$

Circular Thickness or Reference pitch (t)

$$t = \frac{\pi D_p}{2N} = \frac{60 \times \pi}{2 \times 24} = \frac{141.4}{48} = 3.9\text{mm}$$

Addendum (A) = $\frac{1}{P} = \frac{1}{0.4} = 2.5\text{mm}$

Dedendum (B) = $\frac{1.157}{P} = \frac{1.157}{0.4} = 2.89\text{mm}$

Root Diameter (RD) = $\frac{N-2}{P} = \frac{24-2}{0.4} = 55$ mm

Base Circle (BC) = $D_P \times cosPA = 60 \times cos20^o = 56.4\text{mm}$

Circular Pitch (CP) = $\frac{\pi D_p}{2N} = \frac{3.14 \times 60}{2 \times 24}$=3.9mm

Whole Depth (WD) = $\frac{2.257}{P} = \frac{2.157}{0.4} = 5.39\text{mm}$

In designing a gear, it is important to analyze the magnitude and direction of the forces acting upon the gear teeth, shafts, bearings, etc. the Spur Gear's transmission force F_n, which is normal to the tooth surface, as in Figure3.4, can be resolved into a tangential component, F_t, and a radial component, F_r.

$$F_t = \frac{2T}{D_P} \text{--1}$$

$F_t = \frac{2 \times 9000}{60} = 300\text{N}$, **which** transferred in to the pitch of the rack gear teeth

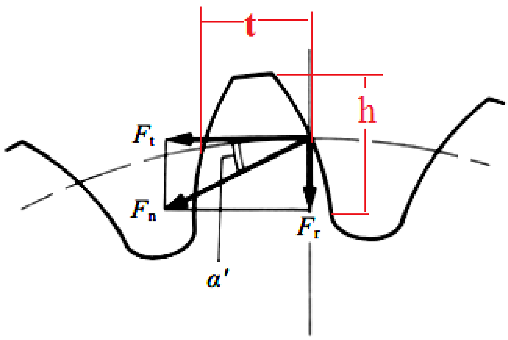

Figure III Directions of forces in spur gear [2]

The force is transferred from the operator in to the handle and then in to diametric pitch of the gear.

Torque At the diametric pitch is became,

$$T_{D_P} = F_{KW} \times r_{D_p} \text{-----------------------------------2}$$

$$F_{KW} = 300\text{N}.$$

$$T_{D_P} = 300\text{N} \times 60$$

$$T_{D_P} = 18{,}000\text{N}$$

By using the Lewis Bending Equation the tangential force exerted in to the gear became.

$$F_t = \sigma_w \times f \times p_c \times y \text{-------------------------------3}$$

$F_t = 17{,}464.68\text{N}$, Ultimate capacity of the spur gear which withstand without failure. Hence the tangential force developed at the spur gear is 3000N, so the ultimate force, which is, F_t=13,971.7N, with stand without failure is more than the developed force.

Design of Helical Springs

The helical spring are made up of a wire coiled in the form of a helix and is primarily intended for compressive or tensile loads. Our aim is to select helical compression spring which absorbs a maximum load of 300N for a deflection of 60 mm. Hence our purpose is to select spring to induce the above load and compressive stress.

With this requirement I have select or decide material of carbon steel with its advantageous the requirement of 60mm deflection. Carbon steel has maximum allowable shear stress of 483Mpa.with average service, and modulus of rigidity of 80MN/mm^2.

Given, F_t=17,464.68N and $\delta = 60mm$

Mean diameter of the spring coil d=0.83mm

Take factor of safety 4, d=0.55×4=2.49mm

From Table, we shall take a standard wire of size standard wire gage (SWG14) having diameter (d) = 2.337mm.

Mean Diameter of the Spring Coil, =14.0mm

Number of Turns of the Coils $n = \frac{60}{1.12} = 54.1 \cong 55\ turns$

For squared and ground ends, the total number of turns,

$$n' = n + 2 = 55 + 2 = 57\ turns$$

Solid Length $L_S = n' \times d = 57 \times 2.337 = 133.2mm$

Free Length of the spring $L_F = 202.6\text{mm}$

Pitch of the Coil p = $\frac{202.6-133.2}{57} + 2.337 = 3.554\text{mm}$

Springs are almost always subject to fatigue loading. In many instances the number of cycles of required life may be small, say, several thousand for a padlock spring or a toggle-switch spring. But the valve spring of an automotive engine must sustain millions of cycles of operation without failure; so it must be designed for infinite life.

Then a steady component and an alternating component can be constructed as follows

$$F_a = \left[\frac{F_{max} - F_{min}}{2}\right] \text{-----------------------------------4}$$

$$F_{mid} = \frac{F_{max} + F_{min}}{2} \text{-----------------------------------5}$$

The maximum force that exert on the spring is that 300N. We apply 80% of the force, which is became 240N, the remaining 20% of force is pre-loaded 60N; with this load we have minimum and maximum load and also maximum and minimum shear stress. [11]

The amplitude and midrange force is became,

Free length of the spring is 300mm, when it is pre-loaded, that is 80% of the force is applied the spring length became,

Maximum force =240N

Minimum force =60N

$$F_a = \left[\frac{F_{max} - F_{min}}{2}\right] = \frac{240-60}{2} = 90\text{N And}$$

$$F_{mid} = \frac{F_{max} + F_{min}}{2} = \frac{240+60}{2} = 150\text{N}$$

The midrange shear stress is given by the equation

$$\tau_m = k_B \frac{8F_m D}{\pi d^3} \text{--6}$$

$$\tau_m = 1.15 \frac{8 \times 150 \times 11.7}{\pi \times (2.337)^3} = 402.6\text{Pa}$$

The maximum and minimum shear stress is,

$$\tau_{max} = k_B \frac{8F_{max} D}{\pi d^3} \text{-----------------------------------7}$$

$$\tau_{max} = 1.15 \frac{8 \times 240 \times 11.7}{\pi \times (2.337)^3} = 644.2\text{Pa}$$

$$\tau_{min} = k_B \frac{8F_{min} D}{\pi d^3} \text{------------------------------------8}$$

$$\tau_{min} = 1.15 \frac{8 \times 60 \times 11.7}{\pi \times (2.337)^3} = 161.1\text{Pa}$$

Then the shear stress amplitude is

$$\tau_a = k_B \frac{8F_a D}{\pi d^3} \text{---9}$$

$$\tau_a = 1.15 \frac{8 \times 90 \times 11.7}{\pi \times (2.337)^3} = 241.6\text{Pa}$$

There is always a risk that the working stress to which a member is subjected will exceed the strength of its material. The purpose of a factor of safety is to minimize this risk. Factors of safety can be incorporated into design calculations in many ways.

Table1: Values of Lewis Form Factor Y [4]

Number of Teeth	*Y*	*Number of Teeth*	*Y*
12	0.245	28	0.353
13	0.261	30	0.359
14	0.277	34	0.371
15	0.29	38	0.384
16	0.296	43	0.397
17	0.303	50	0.409
18	0.309	60	0.422
19	0.314	75	0.435
20	0.322	100	0.447
21	0.328	150	0.46
22	0.331	300	0.472
24	0.337	400	0.8
26	0.346	Rack	0.485

From the above table we find A = 2211Mpa and m = 0.145. The ultimate tensile
Strength is estimated as

$$S_{ut} = \frac{A}{d^m} \text{--- 10}$$

$$S_{ut} = \frac{2211}{2.337^{0.145}} = 1954.9\text{Mpa}$$

Also the shearing ultimate strength is estimated from

$$S_{su} = 0.67 S_{ut} \text{-------------------------------------- 11}$$

$$S_{su} = 0.67 \times 1954.9 = 1309.8\text{Mpa}$$

The Gerber ordinate intercept for shear

$$S_{se} = \frac{S_{sa}}{1 - \left(\frac{S_{sm}}{S_{su}}\right)^2} \text{-------------------------------------- 12}$$

$$S_{se} = \frac{398}{1 - \left(\frac{534}{1309.8}\right)^2} = 477.34\text{Mpa}$$

The amplitude component of strength S_{sa}

$$S_{sa} = \frac{r^2 (S_{su})^2}{2S_{se}} \left[-1 + \sqrt{1 + \left(\frac{2S_{se}}{rS_{su}}\right)^2} \right] \text{------------ 13}$$

$$S_{sa} = \frac{0.67^2 (1309.8)^2}{2 \times 447.7} \left[-1 + \sqrt{1 + \left(\frac{2 \times 447.7}{0.67 \times 1309.8}\right)^2} \right]$$

$$S_{sa} = 806.68 \times [0.4776] = 385.3\text{Mpa}$$

The fatigue factor of safety is given by

$$n_f = \frac{S_{sa}}{\tau_a} \text{-- 14}$$

$$n_f = \frac{379.267}{257.7}$$

$$n_f = 1.47$$

Since the factor of safety is greater than 1, the allowable working stress will be less than the strength of the material.

1.6. Driving Nails

Toe nailing, a common method of joining wood framework, involves slant driving a nail or group of nails through the end or edge of an attached member and into a main member. Toe nailing requires greater skill in assembly than does ordinary end nailing but provides joints of greater strength and stability. Tests show that the maximum strength of toe nailed joints under lateral and uplift loads is obtained by

- Using the largest nail that will not cause excessive splitting,
- Allowing an end distance of approximately one-third the length of the nail,
- Driving the nail at a slope of 30°with the attached member, and
- Burying the full shank of the nail but avoiding excessive mutilation of the wood from hammer blows [12].

According to the American society of civil engineers manuals and reports on engineering practice on no. 84, mechanical connections in wood structures, test loads at joint slips of 0.38 mm (approximate proportional limit load) for bright common wire nails in lateral resistance driven into the side grain (perpendicular to the wood fibers) of seasoned wood are expressed by the empirical equation

$$P = KD^{3/2} \text{--- 15}$$

Where

- P - Lateral load per nail,
- K- Coefficient, and
- D - Diameter of the nail

Conditions

- Wood with a moisture content of 12%,
- Specific gravity based on oven dry weight and volume at 12% moisture content.

Coefficients based on load at joint slip of 0.38 mm (Refer Table1)

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- $P_{5d}=kd^{3/2}=50.04 \text{ x } (2.87)^{3/5}=243.30N$
- $P_{6d}=kd^{3/2} =50.04 \text{ x } (2.87)^{3/5}=281.07N$
- $P_{7d}=kd^{3/2}=50.04 \text{ x } (2.87)^{3/5}=293.18N$
- $P_{8d}=kd^{3/2}=50.04 \text{ x } (2.87)^{3/5}=304.09N$

The working condition of the test considered as the specific gravity of the wood is in range of between 0.29-0.42 for hard wood and 0.33-0.47 for soft wood. So any type of wood that fail between this ranges can be joined with this nail gun hammer.

The above results are indicates, according to 'ASTM', the maximum working capacity of the designed mechanically operated carpenters nail gun is , p_{7d} ,which required 293.18N. So it is bellow or equal to the maximum output of nail gun hammer

1.7. Simulation of Critical Components with Solid Work Software

Static studies calculate displacements, reaction forces, strains, stresses, and factor of safety distribution. Material fails at locations where stresses exceed a certain level. Factor of safety calculations are based on a failure criterion. The software offers 4 failure criteria.

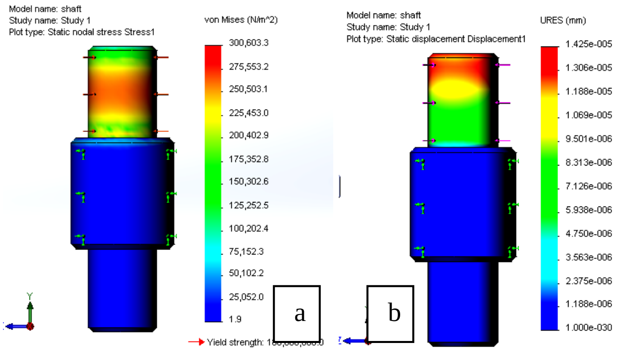

Figure2: Simulation of stress analysis (a) and static displacement (b) on shaft when force applied on the keyway

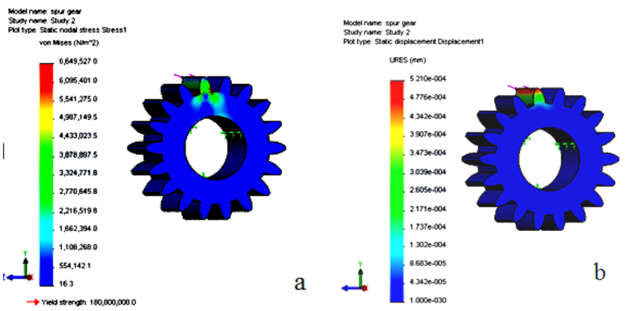

Figure3: Simulation of stress analysis (a) and static displacement (b) on spur gar when force applied on teeth

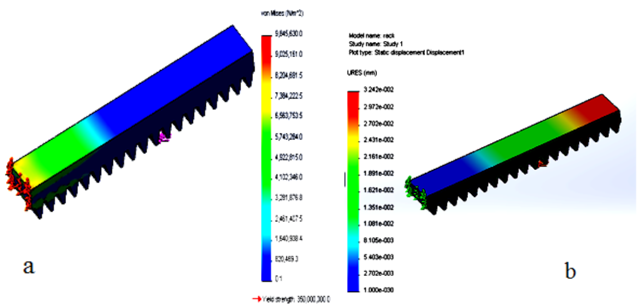

Figure4: Stress simulation (a) and static displacement of rack (b), the green indicates the fixture, and the pink color for location of applied of force

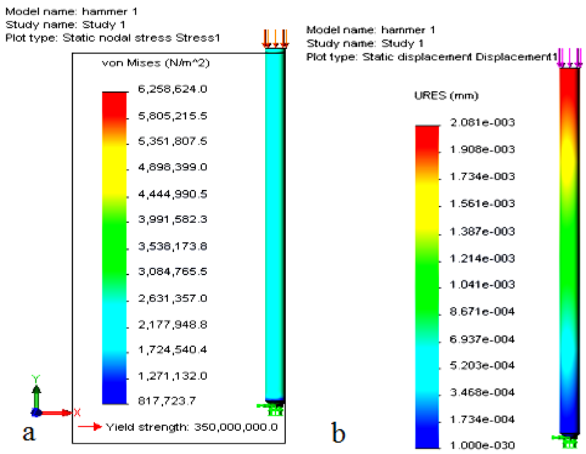

Figure5: stress simulation (a) and static displacement simulation of hammer (b), the green

As we have seen all critical components of the machines are in under the maximum yield strength that the material can absorb without fracture or failure.

1.8. Mechanism of Operating Principle of Nail gun

As we seen mechanically operated carpenters nail gun is powered with compressed spring, the compression force is done by mechanically meshing spur gear and rack gear ,with including buttress thread, in order to fire nails there is slightly small procedures.

Pre-conditions

iii. The nails are available in the magazine; the capacity of the magazine is about 15 nails.

iv. The operator is being held the fixed holding with the right hand.

Once the nail is available in the magazine, the operator is pull rotationally to compress the spring, when the handle is rotate, arm and shaft is also rotate with the handle. To create one directional motion and force application we use buttress thread. When compression spring is reached at ultimate compression limit, we just loose our hand, to make it free from force applying. So the spring is pushing the hammer.

1.9. Conclusion

In our country, traditionally carpenters are using hammers to join woods. Hammers are labour intensive tools, in addition to this, to insert the nail in to the wood it need a perfect target, otherwise the nail may be deflected in to the operator or it may be bended. The working conditions of the carpenters are not conformable and it is tiresome. In order to join two woods, they should hit it up to an average of ten times for a single nail. But this joining technique is labour intensive method.

The current nail guns use compressed air, explosive gases or charge, or an electric motor. The disadvantage of an electric motor nail gun is consumption of electric power and it is difficult to rural areas , the pneumatic nail gun have a hose and an extra equipment, like a pump, that has to be on site at all times. The explosive gas nail guns get rid of the need of the hose, but must be regularly cleaned, and require a battery. The mechanically powered carpenters nail gun solves such type of backwards without any consumption of power source or any other type of accessories.

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The designed gun is meant to shoot a hammer to penetrate wood by nails, in order to do so the hammer must move with fast velocity to pierce the wood by the nail. In the design of mechanically powered carpenters nail gun the mechanism starts at the handle powered by the working man. Ergonomically literatures indicate that one person can apply 196.4N force in case of radial motion continuously for 8 hours.

It is assumed that for safety at the handle 60N force is exerted on the handle, this force is transmitted in to the gear with the help of arm length through the shaft then in to the rack. When the operator pull the handle in radial direction rack will compress the spring, at this stage the energy will store in the spring. While the trigger is released the hammers hits the nail and pierce the woods because of the energy stored in the spring. In the connection between shaft and spur gear there is ratchet and pawl mechanisms, which is capable of transmitting force in one direction and while the rivers is being idle.

By the use of the data generated in the experiment of wood hardness as an input, the analytical result of mechanically operated nail gun have the capacity of producing 300N force. Force and Stress analysis of the selected of critical components of nail gun machine was simulated by using SOLID WORKS Explorer 2012 commercial software, according to the output data (Refer Table 3.4 up to Table 3.7 in the full document), the maximum force and stresses are bellow the ultimate strength of the selected material. The designed Mechanically Operated Carpenter Nail Gun has the capacity penetrate locally available *Cordiana Africana* (wanza) wood spacious with different nail size (5cm, 6cm and 7cm).

1.10. Recommendation

The following are recommendations for related research in Mechanically Operated Carpenters Nail Gun

1. This gun machine can solve the problem of power source and working condition of the carpenters, but it is limited with space utilization, so it is recommend that if this machine is reduced in length it can be more comfortable for the operator.
2. Mechanically Operated Carpenters Nail Gun is portable machine, the outer cover of the body is made from sheet metal, it can be modify by using composite material to reduce the weight and increase appearance of the machine.
3. The experiment of wood hardness is tested on *Cordiana Africana* (wanza) wood specious which is free from knots type of wood; an interested person can test by considering different type of wood specious and the formation of knots.
4. The designed mechanically operated carpenters nail gun is limited up to 7centimetre diameter nail length; so for further work any interested person or group can upgrade it in to the preceding higher nail length and diameter.

REFERENCE

[1] Les Goring, Manual of First and Second Fixing Carpentry, 2008, 2nd Edition, Butterworth-Heinemann is an imprint of Elsevier Ltd
[2] ASTM, Standard Methods for Testing Small Clear Specimens of Timber, ASTM D143-94. West Conshohocken, PA: American Society for Testing and Materials, June 2002
[3] William Ciarniello, Coil gun feeding mechanism, May 2012
[4] http://www.lanfrancdt.co.uk/manufacturing/woodjoints Date of Access, Sep. 2013.
[5] David Lopez Jr. and Mike Ryan, Coil Roofing Nailers, February 2010
[6] Habitat KC, How to Use a Nail Gun, Barelybad.com, 2011
[7] Journal, Safe use of nail gun, February, 2011
[8] John E. Bringers, Handbook of Comparative World Steel Standards, 3rd edition
[9] L.L. Faulkner, Standards for Engineering Design and Manufacturing, 2006, Taylor and Francis Group
[10] http://www.nail-gunaccidents.com/pages/nail_gun_safety.htm, Date of Access, Dec. 2013
[11] Sara Richards, Ergonomic Basics, August, 2005
[12] ASME, Dimensioning and Tolerance, January, 1995
[13] Budynas Nisbett, Shigley's, Mechanical Engineering Design, Eighth Edition, McGraw-Hill
[14] William Simpson and Anton TenWolde, Physical Properties and Moisture Relations of Wood, American Society for Testing and Materials, 1997
[15] Salim Hiziroglu, Strength Properties of Wood for Practical Applications, Robert M. Kerr
[16] Frank Kreith Boca Raton, Engineering Design II Mechanical Engineering Handbook, 1999.
[17] Heinz Tschatsch, Applied Machining Technology, Springer, 2008.
[18] Helmi A. youssef and hassan El-hofy, Machining Technology-Machining Tools And Operation, Taylor and Francis Group, 2008.
[19] James K. wassel, Handbook of Advanced Material, 2004.
[20] J. Paulo Davim, Machining, Springer, 2008.
[21] Michael F. Ashby, Materials Selection in Mechanical Design, 3rd Edition
[22] Ranjender Singh, Introduction to Basic Manufacturing Processes and Workshop Technology, 2006.
[23] Samuel J. Record, and I.S. M.F., The Mechanical Properties of Wood, 1st edition, Chapman and Hal L.imited, June 2002.
[24] Tim Uhler, Coil Framing Nailers, December 2005.
[25] Victor W. Weedn, and Roger E. Mittleman, Stud Guns Revisited, Journal of Forensic Sciences, JFSCA, and Vol. 29; No. 2, April 1984.
[26] Wasim A. Khan and Abdul Raouf, Standards for Engineering Design and Manufacturing, 2006
[27] Y. Yamada, Materials for springs, April, 2007, Food and Agricultural Products Center, FAPC-162, 1998.