International Journal of Research in Engineering and Innovation
(IJREI)
journal home page: http://www.ijrei.com
ISSN (Online): 2456-6934

Design of nail making machine for various industrial work

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Abstract

Design and analysis of a nail making machine that is cost effective for the various industry, this give an overview on the need to have a cheaper design, which is simple and cost effective. From the survey, it was found out that the nail making machines currently in use in the country are very few and were imported from USA, China or India and they came at a cost of around 2500 OMR for this reason, they are only purchased by well established companies. A design of nail making machine involved analysis of its component. From this project, it was shown that it is economical to manufacture the new design of nail making machine locally since the 500 OMR is much lower than the imported machines that cost more than 2500 OMR.

Keywords: Nail making Machine, Designing, Bearing, Crankshaft.

1. Introduction

A nail is a pin-shaped object of metal that is used as a fastener, as a peg to hang something, or sometimes as a decoration. Generally, nails have a sharp point on one end and a flattened head on the other; Nails are made in a great variety of forms for various specialized purposes. The most common is a wire nail; other types of nails include pins, tacks, brads, and spikes etc. Nails are typically driven into the work piece by a hammer, a pneumatic nail gun, or a small explosive charge or primer. A nail holds materials together by friction in the axial direction and shear strength laterally [1]. The point of the nail is also sometimes bent over or clinched after driving to prevent pulling out. A nail consists of a metal rod or shank, pointed at one end and usually having a formed head at the other, that can be hammered into pieces of wood or other materials to fasten them together.

A nail is usually made of steel, although it can be made of aluminum, brass, or many other metals. The surface can be coated or plated to improve its corrosion resistance, gripping strength, or decorative appearance. The head, shank, and point may have several shapes based on the intended function of the nails. Mostly nails are used in residential housing, construction work, industrial application etc.

The average wood frame house uses Sbetween 20,000 and 30,000 nails of various types and sizes.

2. Methodology

2.1 Design Introduction

The ultimate aim of this analysis is to design a cheap and affordable nail-making machine for the various engineering industry in Oman. [2]With the completion of this project, we hope that our nail making machine design will be used widely throughout the multiple engineering fields with suitable scale in Oman.

The objective of this achieved through the subsequent completion of the goals including analyzing all existing nail making design products and determining which one can easily be fabricated using the locally available materials and machines and then determining the overall quality of the nail making machine e.g. in terms of cost of production.

2.2 A survey of nail making machine used

Nail making machine designs available for purchase by the manufacturing and the building industry. These machines are produced overseas by a wide variety of companies in countries like India, China and USA. The different available machines are designed for production of different nail designs. E.g., there are different machines for producing box nails, screw nails, finishing nails, cut flooring etc. and different machines for

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different inches of nails. Our focus on the same was on the nail making machines that are small and efficient.

2.3 Perfect automatic wire nail making machine

It is simple, study in design, and is made from high-grade casting & steel. There is a range of them which can produce flat head nails, pop nails, round head nails, lost head nails, counter sunk head nails, from copper, aluminum & brass [3]Wires. Its main crank is directly driven by motor and side-shafts are driven by four bevel gears to ensure correct and permanent adjustment of the cutting tool. The length and thickness of the nails is adjustable. All tools are easily accessible and can be quickly changed.

The wire end from coil passes through straightening rollers and fed intermittently in the gripping dies, which close firmly allowing heading punch to press the head of the nails, then grip loosened and required length of the nail is fed constantly, where it is cut by cutting tools leaving ample stock for the head of the next nail. [4]Thus, the ejector ejects ready nail. The \ operations are repeated in each revolution. This goes at 650 OMR before adding the shipping costs. This would therefore get to over 1150 OMR.

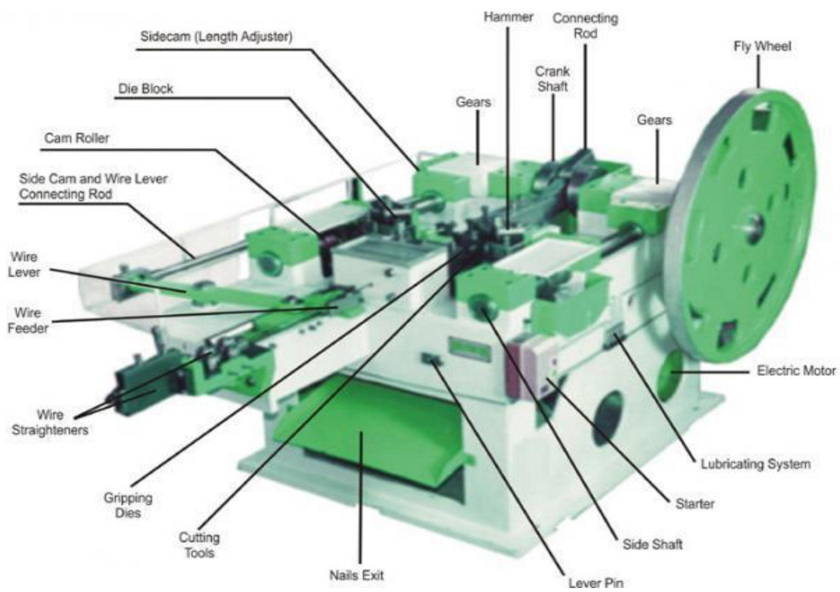

Figure 1: Model of Nail making machine from Punjab, India

2.4 N6-E nail making machine

In this case, the wire form wire coil passes through straightening rolls and fed intermittently into the gripping dies, which close firmly head of the nail. The grip is loosened now and the required length of wire is fed forward. Then the cutting tools cut the point a little forward of the grip leaving sufficient wire projecting to form the head of the next nail. This sequence of operations is repeated at each revolution of the machines and the nails are produced constantly. [5]The frame of the machine is rigid; all moving parts are of ample dimensions and precisely made from quality material, which ensures the smooth running of machine in spite of high rate of output. The wire feed is actuated by means of gears mounted on one side shaft, which moves the feed slide through connecting rod. The bush bearings are made from special metals and provided with continuous approach of oil, which ensures the smooth running and long life. This comes at a cost of 1550 OMR.

Figure 2: N6-E Nail Making Machine

3. Analysis of Machine

3.1 Parts of machine and selection of material

3.1.1 Fastener Materials of a Machine

- Selection of Materials a Machine.
- Chemical and Physical properties.
- Maximum allowable stress.

The machine will work at a speed of approximately 1444 rpm and this requires that the fatigue strength of the moving components be high. The overall weight of the machine is big due to the flywheel, die block and other components. Secondly, we obtained a balance between these requirements and the properties and other characteristics of the materials that are available with regard to the economic considerations. [6]The flywheel, for example, could be made from carbon fiber material and employ magnetic bearings Manufacturing methods contribute to the cost of the machine so while designing, we considered parts that are easily and cheaply machined.

The main material chosen for the nail-making machine is mild steel. This is used in the mountings, L section beams and frame structures. It has the following properties:

- In mild steel composition, other than maximum limit of 0.02 carbon in the manufacture of carbon steel, the proportions of manganese, copper and silicon are fixed, while the proportions of cobalt, chromium, niobium, molybdenum, titanium, nickel, tungsten, vanadium and zirconium are not
- A high amount of carbon makes mild steel different from other types of steel. Carbon makes mild steel stronger and stiffer. However, the hardness comes at the price of a decrease in the ductility of this alloy.
- Carbon atoms are affixed in the interstitial sites of the iron lattice and make it stronger.
- Density is 7.85 gm/cm^3
- Young's modulus is 210Mpa.
- It has ferromagnetic properties, which make it ideal for manufacture of and motors.

3.1.2 Pulley Material

For the pulleys, the most preferred material is cast iron. This is chosen due to the following properties.
Tensile strength – this is about 483Mpa.
Compressive strength is high and can be almost as high as that of mild steel.
Cast iron also shows resistance to deformation.

3.1.3 Bearing Material

Bearings should have properties like good fatigue strength, conformability; embed ability, ant scoring, corrosion resistance and thermal conductivity.
[7], from the following table of bearing materials and their properties, it can be noted that there is not one material with all the above hence a trade-off has to be made to get a material with the best combination of properties.

Table 1: Bearing Material and their properties

Bearing Material	Fatigue Strength	Conformability	Embedability	Anti-scoring	Corrosion resistance	Thermal Conductivity
in base Babbit	Poor	Good	Excellent	Excellent	Excellent	Poor
Lead base babbit	Poor to fair	Good	Good	Good to Excellent	Fair to good	Poor
Lead Bronze	Fair	Poor	Poor	Poor	Good	Fair
Copper Lead	Fair	Poor	Poor to Fair	Poor to Fair	Poor to Fair	Fair to Good
Aluminum	Good	Poor to Fair	Poor	Good	Excellent	Fair
Silver	Excellent	Almost None	Poor	Poor	Excellent	Excellent
Silver Lead Deposited	Excellent	Excellent	Poor	Fair to Good	Excellent	Excellent

3.1.4 Die block Material

The die block can be made of cast iron or cast steel. Cast iron is eliminated in this case due to its brittleness hence its inability to take repeated impact loads during head formation of the nail.

3.1.5 Flywheel Material

Flywheels are the main consideration when choosing a material for the same. The force on a flywheel increases with speed and the energy a wheel can store is limited by the strength of the material from which it is made. [8]If you spin a flywheel too fast, you eventually reach a point where the force is so great that it shatters the wheel into fragments. Strong lightweight materials turn out to be the best for flywheels since they can spin fastest without breaking apart. Steel being the locally available material and cheap is used in this case. The spring can be purchased locally and the types made from annealed steel can be used.

3.1.6 Nail collector material

This is made from sheet metal. It can be galvanized in order to prevent corrosion.

3.1.7 Crankshaft Material

The crankshaft is the main connection and transmitter of power from the motor to the nail head punch hence it should have the following properties for it to work well. It should have:-

- High strength.
- Good machinability.
- Low notch sensitivity factor.
- Good heat treatment properties.
- High wear resistant properties.

For ordinary shafts, the material used is carbon steel of grades 40C 8, 45C 8, 50C 4 and 50C 12. The mechanical properties of these grades of carbon steel are given in the table below:-

Table 2: Mechanical Properties of carbon steel grade

Indian standard designation	Ultimate tensile strength (MPa)	Yield Strength (MPa)
40C8	560-670	320
45C8	610-700	350
50C4	640-760	370
50C12	700	390

3.1.8 Head Punch and Cutting materials

High strength carbon steel is used for the nail head punch and the cutting dies. These have to be hardened to be able to take the impact forces. In addition to that, they should be able to deform the low carbon mild steel for the nail wire. [9]The nail wire mild steel has a composition of 0.05% to 0.26% carbon content with up to 0.4% manganese content.

4. Design and Description of parts of designed nail making machine

The designed nail-making machine has six major systems namely:

1. Power/Driving system
2. Wire feeding system
3. Head forming system
4. Nail cutting system
5. Machine fixture system
6. Nail exit system.

4.1 Power driving system

This provides the driving force for all the components of the machine. This system is composed of the motor, flywheel, pulley system, crankshaft and the connecting rod.

4.1.1 Motor

The machine uses an a.c. motor with the following specifications:

- 2 kW
- 1444 rpm

This will go with a wire of 12 S.W.G (standard wire gauge)2.64 mm

4.1.2 Flywheel

This is a heavy wheel attached to the rotating crankshaft to smooth out delivery of power from the motor to the nail head punch through the crankshaft. The rotating mass is used to maintain the speed of nail making machine while the machine releases or receives energy at a varying rate, i.e. as the nail, head punch hits the nail to form the head and while the cutting dies are severing the nail wire. The motor starts at a low speed and accelerates and while the flywheel also accelerates, it stores energy, which it gives back to the crankshaft as the speed decreases.

Figure 3: Flywheel

The inertia of the flywheel opposes and moderates fluctuations in the speed of the engine and stores the excess energy for intermittent use. The amount of energy stored in a flywheel is proportional to the square of its rotational speed, ω as seen in the equation below.

$$E = \frac{1}{2} I\omega^2$$

Where

E is the energy stored
ω is the angular velocity
I is the moment of inertia of the mass about the center of rotation. The moment of inertia is the measure of resistance to torque applied on a spinning object (i.e. the higher the moment of inertia, the slower it will spin when a given force is applied).The moment of inertia for a solid cylinder is $I = \frac{1}{2} mr^2$
The standard dimensions of a rectangular sunk key for a shaft of diameter 60 mm are as follows: Width of key = 10.125 mm Thickness of key = 4.925 mm.

4.1.3 Pulley system

This is composed of the belt drive and pulleys. The rotary motion of the motor is transferred to the crankshaft through the belt and two pulleys, one at the motor shaft and the other at the crankshaft. The v-belt is suited for the nail-making machine for the following reasons:-

- It is the cheapest power transmission utility
- Does not require axial alignment.
- Easy installation and removal
- Quiet operation
- Cushion the motor and bearings against load changes.

V-belts are made of fabric and cords and molded in rubber while the pulleys are made of cast iron in order to reduce the overall weight of the machine

Table 3: Dimensions of standard V-belts according to IS: 2494 – 1974

Type of belt	Power Range (KW)	Maximum Pitch diameter of pulley	Top Width (mm)	Thickness (mm)	Weight per meter length (N)
A	0.75 - 2	60	13	8	1.06
B	2 – 7.5	115	17	11	1.89
C	7.5 - 20	175	22	14	3.43
D	20 – 150	310	32	19	5.96
E	150 - 350	480	38	23	7.21

Table 4: Standard pitch lengths of V-belts according to IS: 2494 - 1974

Type of belt	Standard pitch length of V- belt in mm
A	645, 696, 747, 823, 848, 925, 1001, 1026, 1051, 1102, 1128, 1204, 1255, 1331, 1433, 1458, 1509, 1560, 1636, 1661, 1687, 1763, 1814, 1941, 2017, 2068, 2093, 2195, 2322, 2474, 2703, 2880, 3084, 3287, 3693

Let us assume with the consideration of central distance between the pulleys the suitable length of belt is 1636 mm.
The V- belt speed can be calculated as follows

$$v = \omega\, r$$

$$\omega = \frac{2\pi N}{60} r$$

$$= \frac{2\pi \times 1444}{60} \times 0.03,\ v = 4.534 \text{ m/s}$$

The diameter of the driven pulley is calculated from the following relations

$$\frac{N_1}{N_2} = \frac{d_2}{d_1}$$

N_1 and N_2 are the rotation speed of motor and driven pulley, we select a.c motor with angular speed is 1444 rpm and driven speed is 400 rpm

$$d_2 = \frac{N_1 \times d_1}{N_2}$$

$$d_2 = 216 \text{ mm}$$

The driven pulley at the crankshaft will therefore have a diameter of 216 mm
With the chosen belt pitch length of 1636 mm, the distance between the driven and driving pulleys is computed as below

$$\text{Sin } \alpha = \frac{r_2 - r_1}{x} = \frac{d_2 - d_1}{2x}$$

Length of the belt over pulley is given as

$$L = \pi(r_1 + r_2) + 2x + \frac{(r_2 - r_1)^2}{x}$$

$r_1 = 30$ mm, $r_2 = 108$ mm and Length L = 1636 mm from table 4. Putting the value in above equation and solve for x, we get x = 601mm.

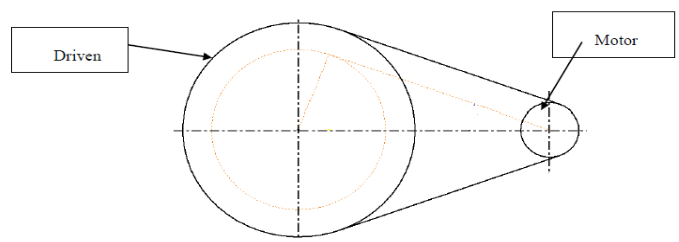

Figure 4: Belt-Pulley free body diagram

4.1.4 Crankshaft

This can be described as an off-centre connection that takes energy from a rotating wheel. Its primary function is to convert rotary motion from the motor to a reciprocating motion required for the head formation by the nail head punch. It can be forged from a steel bar through roll forging or cast in ductile steel. The crankshaft carries high torsion loads and needs to have high fatigue strength. It should also have a good hardness to resist surface abrasion and wear by the parts attached to it. For the nail-making machine, the crankshaft will be composed of pieces of shafts attached together as shown below.

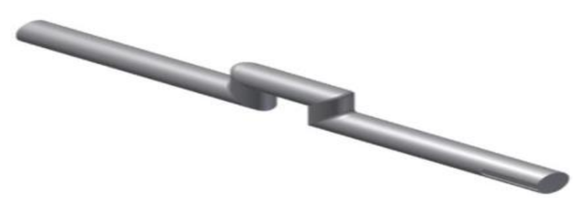

Figure 5: Crankshaft

4.1.5 Bearings

The bearings are used between the crankshaft and the machine frame to maintain separation between the two components. This serves to reduce frictional resistance due to relative motion between contact surfaces.

Figure 6: Bearing

4.1.6 Connecting rod

The motor rotates the crankshaft, which transmits the motion to the nail head punch. In order to do this and maintain the nail head punch motion on a straight line, the connecting rod is used. This is attached to the crankshaft with bushes between them to avoid wear and tear on the two components.

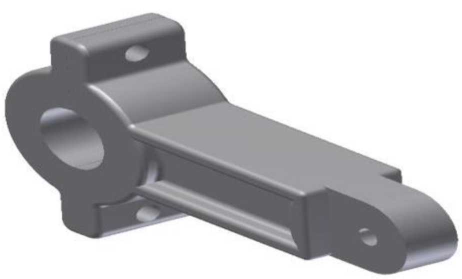

Figure 7 Connecting rod

4.2 Wire feeding system

The basic function of this system is to provide the machine with the raw material for nail making, i.e. the wire. It comprises various components as illustrated all of which play particular roles in the nail making process. They are-

4.2.1 The Rollers

The nail wire is normally kept and moved in rolls. During uncoiling, therefore, there is the tendency of the wire not to be straight. This could cause a problem during head forming as the wire could buckle. To avoid this, the rollers are used. They have a function of straightening the wire as it enters the die block and to remove the effect on the wire due to case hardening since this would necessitate large cutting forces and cause fast wear and tear on the cutting dies.

Figure 8: The roller

4.2.2 The Cam

This offers a controlled wire entry into the die block, which ensures that the correct length of the wire is fed depending on the size of nail required. It also ensures uniformity of the nails in size.

Figure 9: Cam

As can be shown in the diagram below, the cam is profiled in such a way that it moves the wire by a certain distance in every revolution.

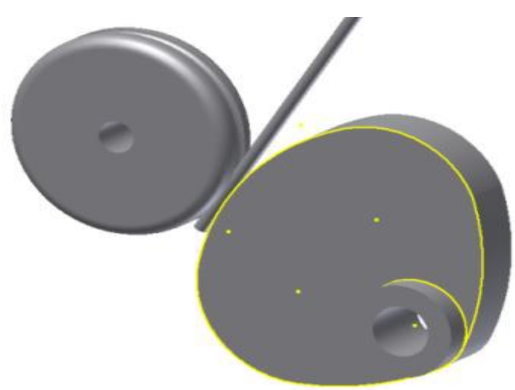

Figure 10: Cam and roller system

The cam presses the wire against the roller hence grasps it. The surface (gripping surface) is hardened to prevent fast wear and tear and to ensure that a considerable force is generated do pull the wire from the rotating roll which is placed next to the machine. After pushing the wire into the die block to the required length (2 inches in this case) the cam rotates freely and the wire is left stationary. This is the time during which the nail is cut and the wire hit to form the head for the next nail. The cam drive is attached to the nail head punch where it draws its motion.

4.2.3 The nail feeder support

It is attached to the die block and carries five straightening rollers and a single roller, which helps to grip the wire as it is being pushed by the cam. It also acts as the support of the wire as it goes into the machine.

4.3 Nail head forming system

This system forms the wire tip hence making it conform to the required shape of the nail head. The nail head forms the hitting surface when using the nail as a fastener. The major component of this system is the nail head punch.

4.3.1 Nail head punch

The function of this is to hit the wire tip hence making it conform to the required shape of the nail head. Its tip is knurled to form the surface necessary for providing friction while using the nail. It is made of high carbon, heat-treated steel for strength and durability. The heat treatment helps prevent chipping or cracking caused by repeated blows on the cut wire. It needs to be strong and sturdy. It should be hard to prevent cracking and chipping during hitting. It is connected to a support which transfers motion from the crankshaft through the Connecting rod.

Figure 11: Nail head punch

The auxiliary components, which support and guide the nail head punch, include; die block, wire gripper, nail guide and the nail head punch cover.
Force required forging the nail head can be calculated as below
Stress, σ is given by: $\sigma = Force/Area$

Making force the subject of the formula, $Force = Stress * Area$
Area of wire acted upon by the force of the nail head punch is given by:

Area $= \frac{\pi d^2}{4}$, where d is the diameter of the wire

Let us consider the diameter of steel wire d = 3mm
Area = $\frac{\pi\ 0.003^2}{4} = 7.065 \times 10^{-6}\ m^2$

Yield strength of the mild steel σ = 248 Mpa
The force P require for punching the steel wire P = 1752 N
The motor speed of the machine N = 1444rpm
Angular speed ω = 151.13 rad/sec
Linear speed of the nail head punch $v = \omega \times r$, V = 0.4523 m/sec

The minimum force required to forge the nail is 1752N as determined above. Putting a safety factor of 2, the actual force imparted on the nail wire is 1752×2 = 3504N.

4.3.2 Nail cutting system

Nail cutting components include the nail cutting die, cutting die lever, sliding roller, cutting die head rail and the return spring.

- Sliding roller
- Cutting die lever
- Nail cutting die
- Return spring

5. Conclusions

The current design of the nail-making machine has overall dimensions of 1588mm length, 635mm width and 804mm height. Focus is laid on the reduction of the bulk and overall price of the machine without compromising on the quality of the nails produced. To achieve this, the working mechanism of the nail-making machine is designed so that the total number of moving parts is reduced to a necessary few. All motion of the nail-making machine is conveyed from the crankshaft to the nail head punch via the connecting rod, and the nail head punch in turn drives the rest of the components, leading to a very simple yet sufficient design of the nail making. This modification aided by sufficient lubrication of the machine has also rendered the machine to be adequately air cooled without the necessity of an elaborate cooling system. Careful selection of materials is observed while considering their availability without compromising on the durability of the nail-making machine once it is fabricated. On the subsequent implementation of the above design, the industry will tend to develop having introduced a business opportunity. This would also come by way of reducing the cost of nails hence a percentage reduction of prices in the construction industry. This project is also aimed at cutting down the prices of nail making machines, which are imported. As is evident from the cost analysis of the nail making machine, it is much cheaper than the existing nail making machines and can be manufactured locally from the available materials.

Operation of the machine is possible under normal conditions as experienced in workshops. Good ventilation is however recommended, as the machine is air-cooled. Ingress of dust should be avoided by maintaining a clean working environment. This gives longer service life for the motor and eventual reduction in the cost of production. This nail-making machine is found out to be economically viable as analysed above. Its implementation has the potential of promoting the manufacturing industry in Oman along with the creation of employment opportunities.

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Cite this article as: Arshad Mehmood Design of nail making machine for various industrial work, International Journal of Research in Engineering and Innovation Vol-3, Issue-2 (2019), 123-130.