Research Article / Review Article FUPRE JOURNAL 9(1):154-162(2025)

FUPRE Journal

of

Scientific and Industrial Research

ISSN: 2579-1184(Print) ISSN: 2578-1129 (Online)

http://fupre.edu.ng/journal

Design, Development and Simulation Analysis of Aluminium Gasket Cutting Machine for Industrial Application

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ARTICLE INFO

Received: 11/01/2025
Accepted: 02/04/2025

Keywords

Development, Design, Gasket, Industrial, Machine

ABSTRACT

This research investigated the design and development of aluminium Gasket cutting machine for industrial application. A gasket is a mechanical seal that closes or fill the spaces between two members basically to prevent leakages must especially when under compression. A gasket cutter is a machine used in the fabrication of gaskets as desired. Gasket therefore are relevant in the oil and gas sector as relevant in the oil and gas sector as leakages of any sort will cause monumental losses. This multiple use imposes a high demand for the product hence the need to domesticate the technology. The method adopted in the design and developed includes the sourcing of local raw materials relevant to the design. All mathematical and scientific principles relevant it is design was developed. The maximum strain of 0.16 was obtained at 0.36 second at maximum Von Mises stress of 2.25 x 10^6 N/m^2. A load of 10N was applied and released in the period of (end time) of 5 seconds. It is more important to note that this study enables one to truly understand and optimize design product performance and utilize the concept of lean engineering. It is hoped that both government and non-government agencies will key with project of mass producing and commercializing this machine, this return would increase the country Gross Domestic Product (G.D.P).

1. INTRODUCTION

A gasket is a mechanical seal that closes or fill the spaces between two members basically to prevent leakages must especially when under compression. A gasket cutter is a machine used in the fabrication of gaskets as desired. Gasket therefore are relevant in the oil and gas sector as relevant in the oil and gas sector as leakages of any sort will cause monumental losses. Gaskets therefor are hard to found in the sizes and uses varies, therefor to solves this problem a gasket cutting machine was conceived, designed and fabricated to meet the industrial demands of local gasket which includes packaging uses, food processing, pharmaceutical, petrochemical, water and gas industry. This multiple uses imposes a high demand for the product hence the need to domesticate the technology. The method adopted in the design and developed includes the sourcing of local raw materials relevant to the design. All mathematical and scientific principles relevant it is design was developed. It is hoped that both government and non-government agencies will key with project of mass producing and commercializing this machine.

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As a result of increased urbanization, roofing elements such as aluminium pieces litters all over the places which finally ends up in most scavenger abode. On the other hand, local filters find it very difficult to access the desired gaskets for various industrial operations.
The project is therefore designed to make use of these aluminium pieces generated from roofing and other ventures to make gaskets of all shapes and sizes capable of solving leakage problems in most industrial setting. To achieve this, a manually operated gasket cutting machine was conceived for design to take care of this problem. With this in place, the problem of gas leakages which most time result to fire outburst will be a thing of the past.

Most of the materials used for the production of valuable gaskets are seen as waste in our immediate environment. These waste constitute environmental problems to man. Hence in order to solve these environmental problems, these materials are harnessed and consorted into useful industrial raw materials such as gaskets.

Again, this work is important and relevant in that problem of getting the desired gaskets for industrial operations will be a thing of the past. This is because; the machine will be capable of producing different sizes and shapes of industrial gaskets to solve and to address both leakage and surface matching capabilities.

Gasket are commonly produced with the following materials depending on it's application and uses. Some of the materials necessary for producing gaskets includes paper, aluminium, silicon, asbestos, fibre and rubber. The studies of gasket production have received a tremendous support from far and wide. Many research articles locally and international abounds, notable of such include Moss et al., 2012. The paper studies and analyzed the various kind of gaskets used in the refrigeration cycle to avoid leakages that many affect the effective performance of the system. Other notable authors that considered gasket applications on Air condition and Refrigeration include (Nash et al 2009, Dammis et al, 2012).

In a related development, Shoup (2011) carried out an extensive study on the design of various machine elements with special interest on the characterization of automobile and industrial gaskets. In the study the paper was concerned with the fluid retention capacity and vibrations among machine elements. Similarly, Trallebory (2022), design and developed flat seal gaskets consisting of twenty (20) products in six (6) products families. These gasket productions were meant to satisfy all industrial requirements of all applications. The paper stressed the need of satisfying harsh chemical medium in aerospace industries, automotive, oil and gas, pharmaceuticals and other processing (food) industries.

Some notable works in the gasket cutting for industrial applications include Okafor (2012). The paper designed and developed manually operated gaskets of various form and sizes and thickness. The machine was able to cut between eight to twelve (8 - 12) gaskets per minutes. The research added that cutting rate decreases with increase to operational time, claimed that it was due to fatigue. The research therefore recommended that less effort should be considered when designing a manual machine of this type that requires human effort. In a relative study, Jain (2008) observed that the high demand of gaskets by oil companies to maintain pressure at all times, automobile industries and air condition and refrigeration industry among other gave rise to the local designs and development of various types and kinds of gasket to meet local demands. Noshirwam et al., (2017) pointed out that gaskets are

blend of material or materials that are compressible in nature. The study further stated that gaskets stop the exchange of fluid among member components.

Thomas et al. (2006) studied the use of aluminium as gasket in the design and fabrication of pleasurable products. The paper highlighted the importance of aluminium used as gaskets to include, its weight advantage, its excellent machinability. The research pointed out that these good qualities of aluminium used as gasket made it possible for it to be used in adverse environments, vacuum pumps to withstand pressures and internal combustion engines where temperature is exceedingly high.

2. METHODOLOGY

2.1 Material selection

In selecting materials for the proper design and development of this manually operated gasket cutter, certain design variables were considered, some of these includes the strength of each material with respect to the assigned designed cask, the fabrication techniques required for such operations, the corrosion resistance ability of the selected material and availability of the materials to be used. Above all, the cost implications of obtaining these engineering materials and the aesthetic value of the mechanism are of greater importance.

2.1.1 Equipment and tools used for the fabrication

In order to fabricate the desired nail cutting machine, certain tools and equipment's are required. These are equipment's used for basic manufacturing process from time to time. They are equipment's commonly found in the workshops. This equipment's again will also assist in the general maintenance of the nail cutter as at when due. This culture of period maintenance will assist in prolonging the useful life of the equipment. Some of the equipment's used includes; the drilling machine, Centre punch, spanners of various types and kinds, hammer, mattock, filling machine, L-square, electric cutting and grinding machine. More so, in order to effectively join the members together firmly, welding machine and its accessories was employed. Other workshop equipment's used for the fabrication and development of the gasket cutting machine includes the screw drivers, the scriber, vernier calipers, vice, anvil, hand files and other hard drilling machines.

2.1.2 Fabrication Procedures

The machine requires a main frame that will house and carry the mechanism for the cutter. The bearing housing will be made to accommodate the bearing that will translate the rotational motion and avoid vibration of other machine members. The punches (plunger) and the main shaft. Assorted bolts and nuts are equally required to fasten the other machine members to give rigidity to the system. Dome of these machine members will be shown in the subsequent chapter of this work.

2.1.3 Materials used for the Design

The design and development of a manually operated gasket cutting machine is made possible by the use and application of the following engineering materials. Some of the materials involved in the construction are: the die, the punch, helical springs, adjustable bundle, angle bars and the rigid base for operation.

i. The die: this is a special machine tool used in manufacturing industries. It is used to cut or make materials to conform to the desired slope and or the intended designed form. They are used for stamping and creating the desired hole by cutting any material placed against it. Dies are used in the manufacture of wires by pressing. They are

equally used for casting and moulding.

ii. Punches: punches come in different shapes and sizes depending on the desired operations. These are majorly four types of punches, they are- the jab punch, the cross punch, the upper cut punch and the hook punch. They all find their applications in design and development of engineering products. Basically, punch and die work together, they cannot work in isolation. Their union is mostly used in the fabrication operations mostly to cut components in sheets materials. A good example of such engineering materials includes – plastic materials, metals and papers depending on the desired application.

iii. Springs: these are different types of springs in the industrial world today. However, their types depend largely on their functions. We have the compression type, the extension helical spring and torsion helical spring. Each as mention end above is designed to carry a specific load. However, the helical spring required for this design and development is the compressive spring.

Most compressive springs are designed to act as compressive force to buffers, it can equally absorb the energy of a desired load.

Helical spring are elastic in nature, coiled in form to store and release energy when needed. Helical springs finds it application in virtually all industrial sections such as transportation, medical, construction industries etc. it can equally serve as dampers whenever needed.

iv. The angle bar: this type of engineering materials comes in different slopes and sizes. They come with different thickness and lengths. Their applications depend largely on the type of designed needed.

Steel angle bar are formed mostly by bending a single desired angle in a piece of steel plate. The most commonly used one is the L-shaped steel which provides support for most engineering design and development. For the sake of the project, the angle bar is used for framing to provide support for the gasket cutter.

v. Bolts and nuts: for the purpose of easy assembly components in nuts becomes an essential component in fabrication. Bolts and nuts are mechanical fasters basically used to hold firmly two or more parts in an assembly. The advantage of using bolts and nuts in any fabrication stems from its ability to be easily disassembled when the need arises.

Bolts are made of heads and cylindrical body mostly with screw threads along some desired length of the body or all the lengths depending on its application. Nuts on the other hand are seen as the female components with internal treads to match the bolts. Most times thread washer are used in between bolts and nuts to avoid crushing and loosing of each member components.

vi. Types of gaskets materials: gaskets are of various types and kinds, basically, four major types of gaskets exist for use in the industry. They include metal gaskets, the non-metal gaskets, the polymer gaskets and the hybrid type. Gaskets are classified according to the materials used for making it. It is important to note that gaskets are compressible materials or blend of materials used between two stationary engineering

materials/component member. It serves as a boundary applicator between these members against the exchange of fluid/liquid over the mating surfaces of the mechanical coupling. The gasket material used for each medium must be able to withstand the maximum temperature and pressure of the medium. Also, the material used for such operations must be impervious to the medium. By this we mean that the material used as a gasket must not allow fluid to pass through it, otherwise, failure is bound to occur.

2.2 Design Calculations

The determination of the qualitative and quantitative values of various components are done using mathematical principles. Therefore, all materials used where calculated for in terms of values and analysis following laid down engineering principles of design and development.

2.2.1 Operation force required

In order to carry out the work of proper gasket cutting, a force is required. This force is called the blanking force; it is the force required to cut the gasket off from the material. The force is therefor given as:

$$F = \frac{l \times t \times S \times f}{2000} \quad (1)$$

Where; F = blanking force given as

l = Required circumference

f = Factor of safety (x2)

t = Thickness of the materials used (1.5mm)

and s = shear strength (75MN/m^2)

$$\Longrightarrow F = \frac{(3.142 \times 0.040) \times 75 \times 10^6 \times 2 \times 0.0015}{2000}$$

$$= \frac{0.126 \times 75 \times 10^6 \times 2 \times 0.0015}{2000}$$

$$= \frac{0.126 \times 75 \times 10^6 \times 0.0015}{2000}$$

$$= \frac{0.28 \times 10^6}{2000}$$

$$\therefore F = 14.1N$$

Hence, the blanking force = 14.10N

But power p = force x velocity

$$\therefore P = 14.1 \times velocity$$

In other to get the velocity, we have the slider displacement (x) is given by

$$X = \gamma \cos\theta + L\sqrt{\left[\left(\gamma/_L\right)Sin\,\theta\right]^2 - 1} \quad (2)$$

Where,

$$\gamma = designcrack\ length = 0.05m$$

$$\theta = crack\ angle = 45^0$$

$$L_1 = crack\ angle = 45^0$$

$$Displacement\ (X) = 0.05(cos\ 45) + 0.12\sqrt{1 - [(0.05)Sin\ 45]}$$

$$X = 0.014M = 7.7mm$$

Finding the velocity of the slider, we have:

$$X_2 = V\gamma w(Sin\,\theta + \frac{Sin\ 2\,\theta}{2\,L\,cos\beta}) \quad (3)$$

Where:

w =angular velocity of the crack

and

$$\beta = \sqrt{1 - \left({}^{\gamma}/_{L}\right)^{2} Sin\theta}$$

(4)

$$= \sqrt{1 - \left(\frac{0.05}{0.12}\right)(Sin45)^{2}}$$

$$= \sqrt{1 - 0.1736\ (0.5)}$$

$$\therefore \beta = 0.96$$

$$But\ N = \frac{2\pi N}{60} = \frac{2\times 3.142\times N}{60}$$

(5)

Recalling that X_2 = V = 0.0.5 (7.40)

Therefore, velocity o slider crack = 0.345m/s

The acceleration of the slider crack 'a' is given by:

$$a = X = W^{2} r\ (cos\theta + {}^{r}/_{L} \cos 2\theta)$$

$$= 7.54^{2}(0.05) \times (cos\ 45 + \frac{0.05\ cos\ 90}{0.12})$$

Therefore, the former required to cut 1.5mm felt is given as 0.142 horse power. Since the mechanism is namely operated, it therefore shows that a minimal amount of energy will be required to operate the machine.

Nonetheless, if the machine was to be automated, what is required us the selection of a sizable and workable pulley and its grove and belt or chain to drive the mechanism.

It is hoped that on successful completion of this manually operated gasket cutting machine, effort will be made to automate it and details analysis carried out, in order to establish its cost benefit analysis.

3. COMPUTER SIMULATION/MODELING AND ANALYSIS

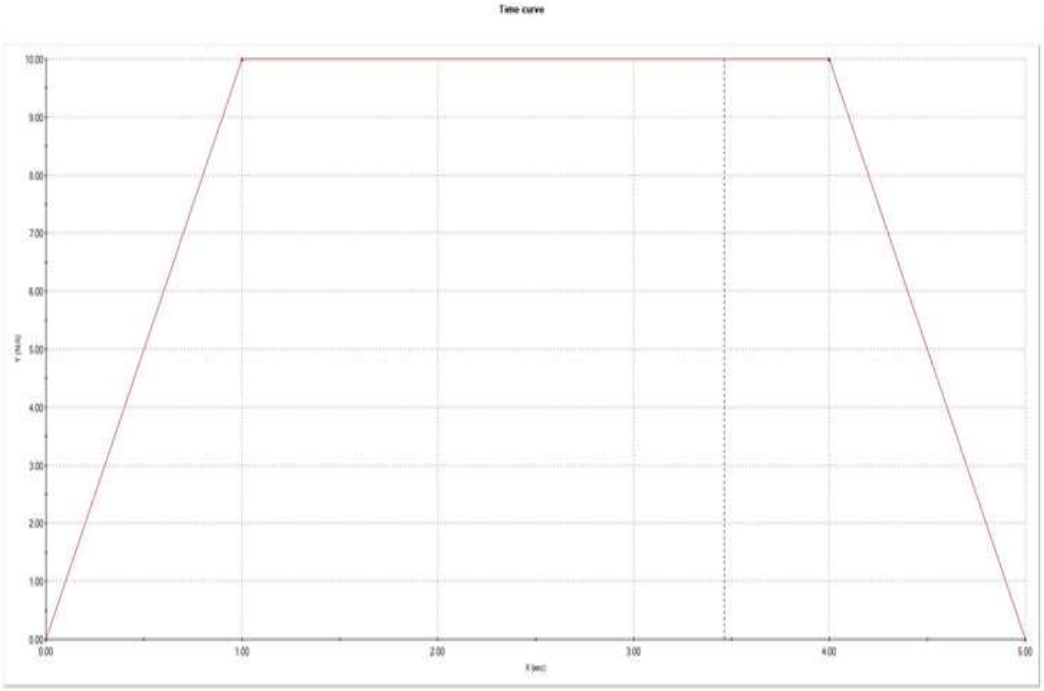

Figure 1: The graph above shows loads against time.

A load of 10N was assumed to be constantly applied and released in the period of (end time) of 5 seconds and subsequent results were seen in

the pictorial charts above for the stress, displacement and strain. Notwithstanding, the stress and displacement response graph of the assumption is also pictured below.

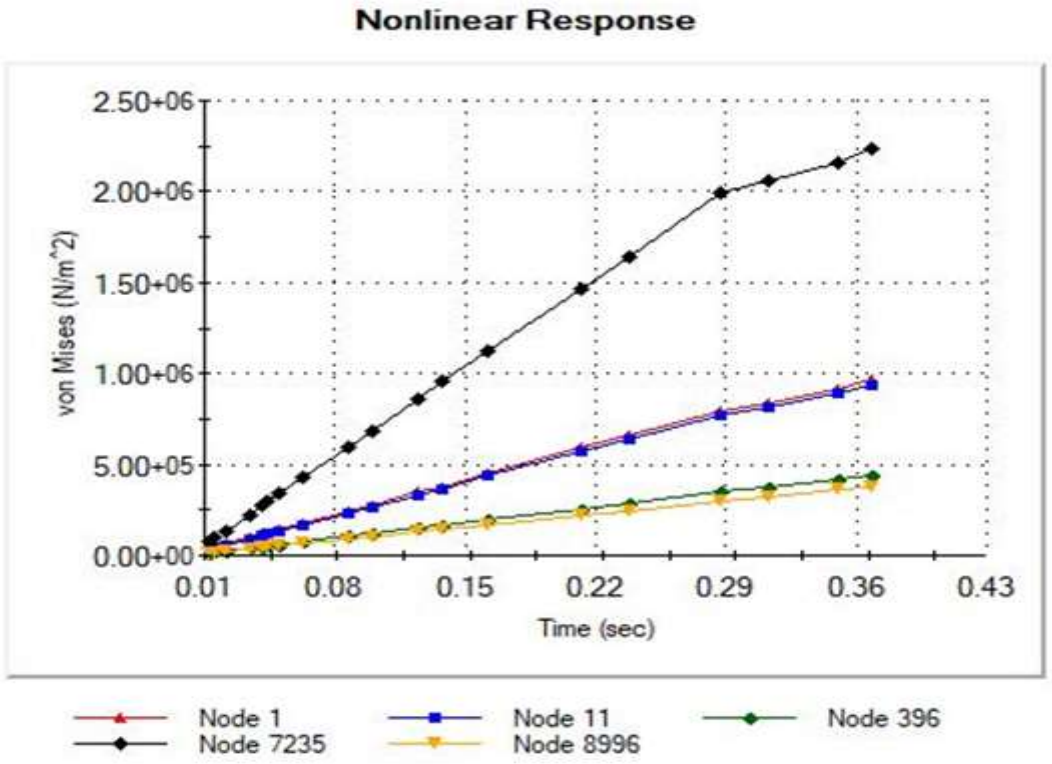

Figure 2: **Gasket Cutting Machine-Time Varyiing Load Simulation-Response-Response1**

The resulting mesh nodes seen on the chart plot describes their stress-time reaction. We selected stresses at different nodes and observed their reactions with time. The same consideration is applicable for the displacement-time graph below. That means that an array of random nodes were selected and their reaction or results were observed against time.

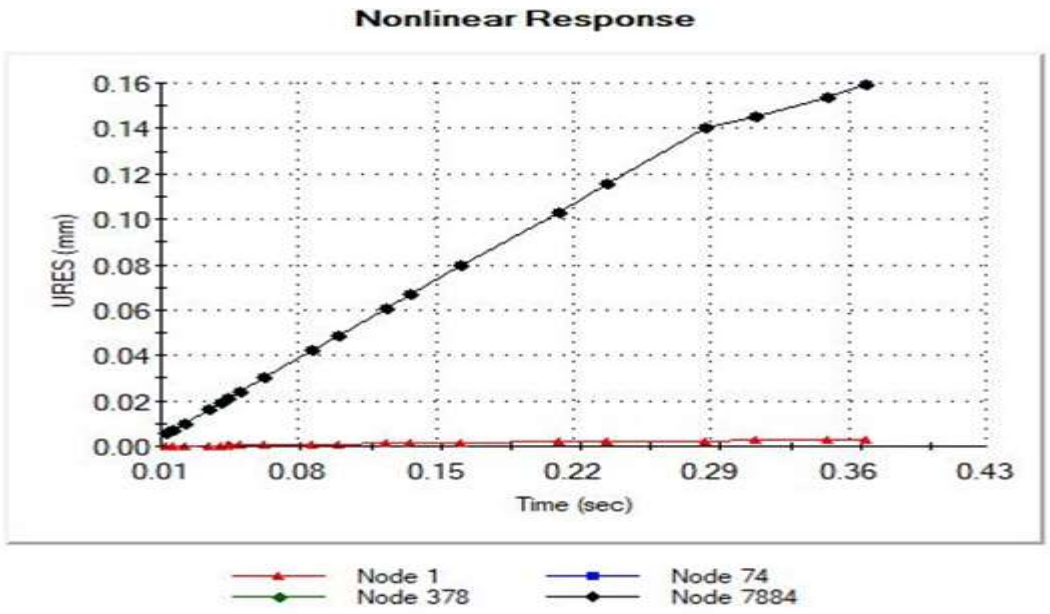

Figure 3: Gasket Cutting Machine-Time Varyiing Load Simulation-Responses

From the simulation results, it was observed that, the region where stresses, strain and inherent material displacement are prominent. The maximum strain of 0.16 was obtained at 0.36 second at maximum Von Mises stress of 2.25 x 10^6 N/m^2. It is more important to note that this study enables one to truly understand and optimize design product performance, helping us tick the boxes of design properties and utilize the concept of lean engineering. Whether the design is a part failure or poor usability, this study has helped us detect the foreseen design problems or design that may arise in due time.

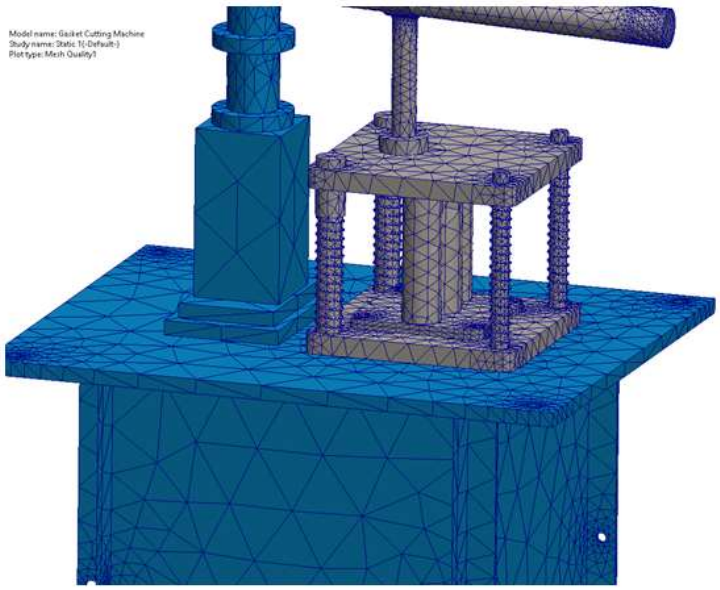

Figure 4: Finite Element modelling of the Gasket cutting machine.

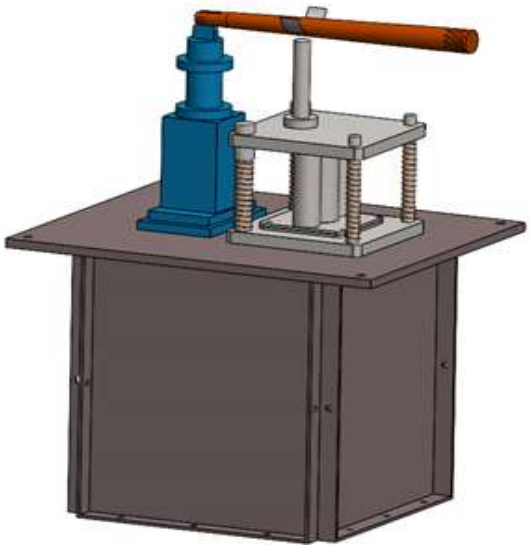

Figure 5: Full solid view of the Gasket cutting machine.

4. CONCLUSION

This project work has conceived, designed and developed a low cost, efficient and reliable aluminium gasket cutter, using locally sourced materials for development. This aluminium gasket cutter is capable of cutting gasket at the rate of 1.5 seconds when an experienced workman operates the machine. The maximum strain of 0.16 was obtained at 0.36 second at maximum Von Mises stress of 2.25 x 10^6 N/m^2. A load of 10 N was applied and released in the period of (end time) of 5 seconds. It is more important to note that this study enables one to truly understand and optimize design product performance and utilize the concept of lean engineering. The project's major objectives were the convert the waste generated from aluminium roofing materials to wealth by converting the same into gaskets useful for most industrial applications on one hand and creation of employment on the other hand when mass produced. It is obviously clear that the objectives have been achieved. The finite element analysis carried out showed the critical components of the machine that must be observed carefully during and after operations. The activator lever specially was noted as a result of the consistent cyclic loading that may affect its reliability over time. However, using Pareto's Principles as a guide, the machine therefore can be used according to the boundary conditions without fail.

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