Development of a Changeable Die Forging Machine for Small Scale Forging Industries

B. Kareem
Department of Mechanical Engineering,
Federal University of Technology, Akure, Nigeria

Abstract: Many local forging industries are witnessing a desideratum in output everyday as a result of continual presence of crude methods of operation in such industries. In this study, mechanisation of the local forging process is achieved by developing a low cost changeable die forging machine using locally sourced material. In the development, the components designed for include cam and follower, camshaft, keys, die pins and the anvil. The cam and hammer are so designed such that their operation is simple and effective. The designed components were then fabricated and assembled. The test carried out on the assembled machine shows that it can work effectively on metals with energy of penetration limited to 30 Joules.

Key words: Die forging machine, desideralum, crude method

INTRODUCTION

Forging is the mechanical working of metal into a useful shape either by hammering or pressing. Most forging operations are carried out on hot metals in local blacksmith shops while some in cold nature of working metal. However, the forging hammer methods are more popular with local blacksmiths rather than forging press. This consists of the use of hammer to beat the working metal rest on the anvil and held there with the aid of the tong. This local process of forging, apart from excessive efforts involved could be hazardous for the operator of such system. Minimisation of such efforts and risks could be possible through the adoption of a mechanized system of operation. Such a mechanized process could be meaningful only if it is affordable, in term of cost, to the local forging practitioners.

Crude methods of forging with the use of hand (with hammer and anvil) could be evidenced from some generations after the creation of Adam with the revelation of iron. By then cutting instrument forgings were the areas of focus. In the later time, water power was utilised to drive the hammer into the anvil. This system was transformed to double-acting steam hammer in 1838. The use of metal die was not in existence until the middle of the nineteenth century when metal dies were introduced with sufficient accuracy to permit the production of parts closer to required dimensions. This process is made possible with the use of machined dies and massive power-transmitting equipment[1]. Most of these massive forging equipment are very expensive that fewer of the local forging operators could afford them.

To this end, this study develops a changeable die forging machine using locally sourced material. The dies are made changeable to be flexible enough to cater for wide range of forging activities in the local blacksmithies. The cam and hammer are so designed such that their operation is simple and effective. This makes it different from complex and expensive old designs as reported by previous researcher[1]. The old designs made use of pivoted beam and is either driven by water or electric motor, while in this design cam and follower mechanism driven by electric motor is used. Also, the mechanism involved in the design has greatly reduced the space occupied by former designs which made use of pivoted beams[2]. Efforts at mechanizing the local forging facilities had been made earlier. One of these efforts develops a mechanized heat treatment bath to replace the tedious local method of cooling hot forged products[3]. This research work has complemented the earlier efforts focusing at developing local contents[4-6] among others.

MATERIALS AND METHODS

In machine development, the components (elements) designed for include: cam and follower (which refers to as hammer based on the function it performs), spring (which maintains contact between cam and hammer at all time during operation), camshaft (on which cam rotates), key (that holds the cam firmly to the shaft), die pins (on with the security of the top and bottom dies lies) and the anvil (that houses the bottom die and at the same time acts as a support to the work when being struck by hammer tup). The cam and hammer are so designed such that their
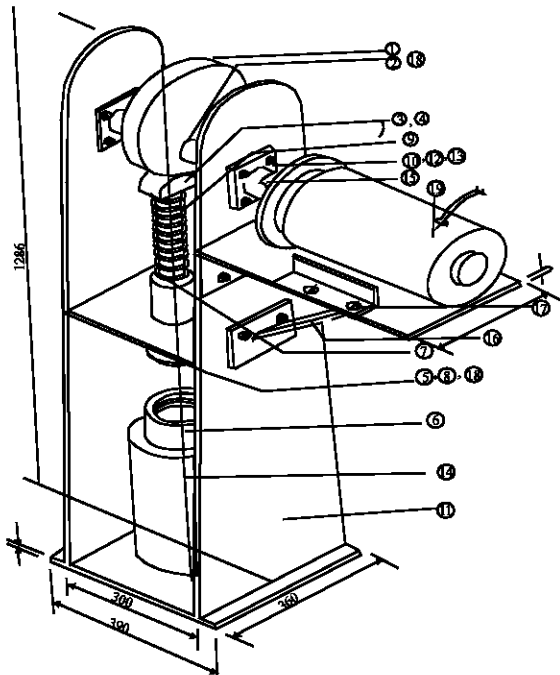
Fig. 1: Isometric drawing of the forging machine

operation is simple and effective. Based on the design outputs, appropriate materials were selected. The material used ranges from high carbon to low carbon steel, some of which were scrapes from discarded automotives and other machineries littering every nook and cranny of Nigeria. Spring and bearing are bought out items while others were fabricated locally using machine tools and welding equipment. The configuration of the developed forging machine is shown in Fig. 1. The design procedure for each of the machine elements are as follows:

Cam and follower (hammer): Cam and follower are designed by considering various factors, parameters and conditions laid down by the identified past works[7-9]. With a speed (N) of 180 rev/min obtained from electric motor and length (L) of 0.15 m of follower with mass (m) of 10 kg, the velocities (mean velocity, V_{mean} and maximum velocity V_{max}) and the acceleration, a were obtained thus: $V_{mean} = \omega L/\theta$, $V_{max} = 2 \omega L/\theta$ and $a = 4 \omega^2 L/\theta^2$ which are 0.9m/s, 1.8m/s and 21.6m/s², respectively, where ω is angular velocity and θ is in Π radian. Based on the computed velocities of follower the minimum and maximum diameters of cam were established to be 0.1 and 0.2 m, respectively. Force (F) on hammer is due to its weight and inertia; both acting together on its downward stroke. With mass, m = 10 kg of the follower and acceleration due to gravity g = 9.81 m/s², F = mg + ma = 315 N. Then energy of blow (W) is given as FL = 48

Joules while torque, T required by machine was obtained from T = 2W/θ = 32 Nm, while the mass and thickness of cam was estimated to be 18 kg and 38 mm, respectively based on the force transferred from the follower. Power P required by machine was computed from relation T ω to be 650 Watt. Hence a minimum of 1 horse power electric motor was recommended to drive the machine.

Spring design: The spring is useful in maintaining a perfect contact of the cam and follower. With the spring strained from its normal position, the strain energy with preload was estimated from relation mgL + ½FL to be 38.34 J, where the values of m, g, L, F are as defined above. Strain energy is the energy stored in spring when it is being deformed. Then spring force was obtained based on the strain energy to be 512N. The spring rate K was 3414 N/m based on emerging spring force. These results led to the selection of carbon steel valve spring of helical type[10]. With length L (0.15 m) of deflection of the helical spring due to load P (512 N), minimum coil diameters d (3.5 mm), maximum coil diameter D (45.5 mm) and Modulus of Rigidity G (79.3×10⁹) for helical carbon spring, the number of active coils n was obtained from relation d⁴GL/(8PD³) to be 5 coils. 8 coils spring was selected to cater for wear during service[10].

Cam-shaft design: Weight carried by cam-shaft consists of weights of cam and follower which was estimated to be 300 N from the known masses of the stated elements. The maximum bending moment for the concentrated load was computed to be 24 N while the diameter cube of the shaft for combined torsion and bending moments including fatigue and shock was obtained from relation[10] (16/$\Pi\tau$) $[(K_b M_b)^2 + (K_t M_t)^2]^{1/2}$ to be 32 mm. Where K_b and K_t are combined shock and fatigue factor for bending and torsional moments, respectively (which is 3.0 for suddenly applied load), shear stress ô is 40 MN/m² for shaft with keyway, M_b and M_t are bending and torsional moments which are estimated to be 24Nm and 32 Nm, respectively and Π is taken to be 3.142. Square key of length 20 mm, thickness and breath of 8 mm and height of 4 mm was selected for its ability to resist built up shear and compression stresses.

Pin design: There are two pins in the design namely hammer pin (which is used to locate and secure the tup onto the hammer) and the die pin (which is used to locate and secure the top die onto the tup. The hammer pin is subjected to only bending moment and the pin diameter cube was obtained using the relation (16/$\Pi\tau$) $[(K_b M_b)]^2$ to be 8 mm (with K_b equals 2 for load suddenly applied to stationary shafts and τ equals 55 MN/m² for shaft

Table 1: Component, material, fabrication technique and cost of the developed forging machine

Item no	Description	Material (in mm. where applicable)	Quantity	Rate (Naira)	Amount (Naira)	Fabrication method
1	Cam	High carbon steel	1	2100	2100	Machined
2	Cam-Shaft	Medium carbon steel	1	500	500	Machined
3	Hammer	Medium carbon steel	1	400	400	Machined
4	Hammer tup	Medium carbon steel	1	500	500	Machined
5	Top die	High carbon steel	1	400	400	Machined
6	Bottom die	High carbon steel	1	900	900	Machined
7	Hammer-pin	Medium carbon steel	1	30	30	Bought out
8	Die-pin	Medium carbon steel	1	20	20	Bought out
9	Spring	High carbon steel	1	260	260	Bought out
10	Bearing	Alloy steel (SKF62/32)	2	400	800	Bought out
11	Support	Mild steel	1	4500	4500	Welded
12	Bearing housing	Mild steel	2	200	400	Machined
13	Bearing cover	Mild steel	2	40	80	Machined
14	Anvil	Low carbon steel with high carbon steel top	1	10000	10000	Welded
15	Coupling	Cast iron	2	400	800	Bought out
16	Motor support	Mild steel	1	800	800	Welded
17	Bolts and nuts	M10x40	18	15	270	Bought out
18	Keys	Hardened steel	3	30	90	Bought out
19	Electric motor	180 RPM, 1 HP	1	5000	5000	Bought out
20	Machining, welding, painting and others				14500	
Total (in Naira)					42, 350	

without keyway) while the die pin diameter cube was also estimated using similar relation (with different magnitude of bending moment, since their weights are different) to be 6 mm.

Anvil design: The anvil was designed to be able to absorb energy (weight) emanated from the struck of hammer, the bottom die and the work piece. These were sum up to be 475 N, with grand total of 650 N when allowance of 35% was added, a 10% increase to the amount recommended for press forging[11]. Therefore the steel of weight 650 N, diameter 180 mm and height 330 mm was selected based on design ouputs.

Construction/assembly details: The cam and the hammer were mounted vertically with the hammer offset 35 mm to the cam centre. The cam is keyed to the cam shaft and it was suspended using two supporting frames housed the bearings that provided smooth rotation for the camshaft driven by electric motor. The force provided by the spring and the spring guide maintained contact of both the hammer and the cam during operation. The anvil is located directly under the hammer tup but at some distance away from it, providing an allowance for the dies and the down stroke of the hammer tup. The anvil is fixed to the base plate welded to the shaft supporting frames. The isometric drawing showing assembly of various parts of the machine is shown in Fig. 1. The parts, material, method of production and cost analysis of fabricated machine is shown in Table 1. From this Table a sum of N42, 350.00 was estimated as the cost of producing a unit.

RESULTS AND DISCUSSION

The test was carried out on the assembled machine in the Department of Mechanical Engineering, Federal University of Technology, Akure, with metal sheets of various grades (in cold condition). The test on ductile metal sheets (for example aluminum) with thickness less than or equal to 1mm was successful under cold forging operation. Better result than this is likely when hot forged. The test result further showed that the machine can work effectively on metals with energy of penetration limited to 30 Joules (which is the 60% of the designed energy). This generated energy is enough to support the varieties of work done in small scale forging industries[12].

CONCLUSION

Development of the changeable die forging machine has thrown hope into the mind of operators of the cottage blacksmithies, especially in Nigeria, many of which cannot afford a costly and scarce heavy-duty forging machines produced abroad. The die of the machine is made changeable to be able to accommodate the varieties of jobs commonly brought by the customers to the forging industries. Besides, the energy generated from the hammer during power stroke is sufficient to support the activities in the local blacksmithies. The cost of a unit machine developed was estimated to be forty two thousand, three hundred and fifty naira (N42, 350:00) only. This cost could be reduced greatly if Government or an individual supports its mass production.

ACKNOWLEDGEMENT

REFERENCES

1. Higgins, R., 1974. Engineering Metallurgy. Edward Arnold, London.
2. Church, A., 1957. Guillet's kinematics. John Wiley and Sons Inc., New York.
3. Oke, P.K. and A.A. Aderoba, 2000. Mechanisation of heat treatment facilities in Local Blacksmithies, Nig. J. Eng. Manag., 1: 20-26.
4. Oke, P.K., 2005. A comparative study of quality of automobile spare parts produced in Nigeria, Nig. J. Ind. Sys. Stud., 4: 1-7.
5. Raji, N.A., 2005. Design and fabrication of narrow belt sanding machine for small scale workshops, Nigerian J. Industrial and Sys Stud., 4: 52-57.
6. Raji, N.A. and N.I. Nwachukwu, 2005. Indigenous development of a venturi meter, Nigerian J. Industrial and Sys Stud., 4: 35-43.
7. Lent, D., 1961. Analysis and design of mechanism, prentice-Hall Inc., USA.
8. Town, H.C., 1971. The design and construction of machine tools, Illffe Books, London.
9. Hannah, J. and R. Stephens, 1984. Mechanics of Machines, elementary. Edward Arnold, London.
10. Shigley, J. and C. Mischke, 1990. Mechanisms: A mechanical designers' workbook. McGraw-Hill Inc., USA.
11. Pritchard, R., 1981. Technician manufacturing technology II. Hodder and Stroughton, London.
12. Dieter, G., 1986. Mechanical metallurgy. McGraw-Hill Inc., USA.