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Research Article

Productivity improvement of AK 103 assembly line

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Abstract

In particular the paper leads to minimize the assembly time and reduction of product cost that is maximized because of wastage due to crack. The objective of this research was to maximize assembly productivity for AK103 at Gafat Armament Industry. The assembly system was analyzed using layout to represent assembly line and table to represent sub-assemblies. The time needed for each process is also studied. By maintaining the idle machineries and introducing continuity of assembly, the current annual capacity of assembly factory can be improved to 3400 products. Design and development of two jigs performed using available technology in industry. The jigs were tested and both jigs work well with some recommended corrections. One method of improving productivity was specifying cause of crack of the components. Study was made on 234 samples at different time for different purpose. For force fitted components, tolerance was also checked taking 3 samples for each fitting components. The other methods used to reduce assembly time were design of new assembly process layout and stating of recommended solutions for inefficient equipments. By appropriate designed layout and recommended corrections of machineries, production capacity may increase from 3400 to 20580 is conceived.

Keywords: *Assembly lines, assembly factory, crack, AK 103, assembly time*

1. Introduction

The product AK 103 is improved feature of AK47. AK47 is named after the Russian designer of the product; Avtomat Kalashnikova during Second World War in 1947.AK103 was manufactured and assembled in Gafat Armament Industry (GAI), defense industry managed under Ethiopian Metal Corporation 15km far from Bishoftu. It is about 80 km from Addis Ababa, producing lightweight armament components. Due to not standard layout of assembly system is not efficient.

Different type of machineries and equipments were used in assembly factory. The machineries that were available in assembly factory are bench drilling, hydropower press, spindle pedestal drilling, polishing, spindle bench drilling, horizontal oil press, disassembly machine, keyway milling, piston assembly, buff grinding, position frame assembly, barrel cleaning, oil pressing, disassembly m/c, compressed jig, pantho-graph (copying), pedestal drilling, hydro power press, circular grinding, tool grinding (polisher), buff grinding, copy milling, manual press and hoist.

2. Literature Review

In every industry assembly line layout design is important task [S.S.Kuber *et.al,* 2014], which are affects the productivity of the company. Type of layout selection to develop assembly line is mainly depends on production rate and the demand [Mark Allington *et al*, 2006], which decides the preferable layout type [Amir J. Khan *et.al*, 2013].

A good layout can provide real competitive advantage by facilitating material and information flow processes [Mahendra Singh *et al*, 2012]. Layout involves the allocation of space and arrangement of equipment's in such a manner that overall operating costs are minimized [Mahendra Singh *et al*, 2012].

In present situation space utilized improperly and the operator and material flow is more, which affecting the productivity. Lean concepts mainly aimed to improve productivity and reduce wastes [Biman das *et.al*, 2014]. It is therefore important that businesses also focus on the accounting system and measurement methods to change from traditional thinking to lean thinking by accessing data and reports that support lean manufacturing (Maskell& Kennedy *et al*, 2007).

In today's fierce competition, productivity is an important factor for a company's success and particularly Sweden is known for its world class development and productivity (Almstrom P. *et al*, 2007). Integrating of parts and components is one of the ways of reducing of assembly time in design for assembly. To integrate the components, the following three considerations have to be taken into consideration [Boothroyd Dewhurst *et al*, 2002].

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One of the most important manufacturing processes of armament is the assembly process that is required when two or more component parts are to be secured together [Daniel E. Whitney *et al*, 2004]. Ideas and concepts of armament have brought significant improvements in the assembly methods employed in high-volume production [Geoffrey Boothroyd *et al*, 2005].

The history of assembly process development is closely related to the history of the development of mass-production methods. The pioneers of mass production are also the pioneers of modern assembly techniques. Their ideas and concepts have brought significant improvements in the assembly methods employed in high-volume production [Geoffrey Boothroyd *et al*, 2005].

Assembly line balancing often has implications for layout improvement.The assembly line is a moving that passes a series of workstations in a uniform time interval called the workstation cycle time (which is also the time between successive units coming off the end of the line).The total work to be performed at a workstation is equal to the sum of the tasks assigned to that workstation [P. R. Olsen *et al*, 1978].

The concept of interchangeability was crucial to the introduction of the assembly line at the beginning of the 20th century, and has become a ubiquitous element of modern manufacturing [Lee Peterman *et al*, 2011].

3. Research Methodology

In this section, methodologies that are conducted to perform this work are discussed. Descriptions followed to study the current assembly system and to integrate the components of AK 103 in order to reduce the number of components so that to reduce the assembly time. Methodologies such as hardness testing after heat treatment and crack testing for the samples from different manufacturing processes to specify cause of crack are discussed. In addition, methodology for developing of jigs and design of new process layout are also discussed. The research work has looked at reducing assembly time by integrating components.

3.1. Analyzing Current Assembly System

To analyze the current assembly process the typical layout and subassemblies; (a) Clarifying the assemblies and components in subassemblies (b) Representing the current assembly process with layout, and (c) Study of the total time needed for each assembly process were initially considered.

Integrating parts and components to reduce assembly time and cost are considered by methods such as;

- Analyzing the machining processes for the parts in time of separated and integrated.
- Model of the integrated part using CATIA software
- By Identifying Cause of Cracks during Assembly, *Investigate Material Composition and Inspection of parts at different steps of the process*
- Design jigs and fixtures to increase productivity in assembly of components
- Design of new assembly process layout

The equipment's used to manufacture this part were (1) Rotary cutting machine to prepare parts in their designed geometry (2) Arc welding machine to join the prepared components (3) Helical spring coiling machine for spring in the loader and (4) Drill machine for piercing holes.

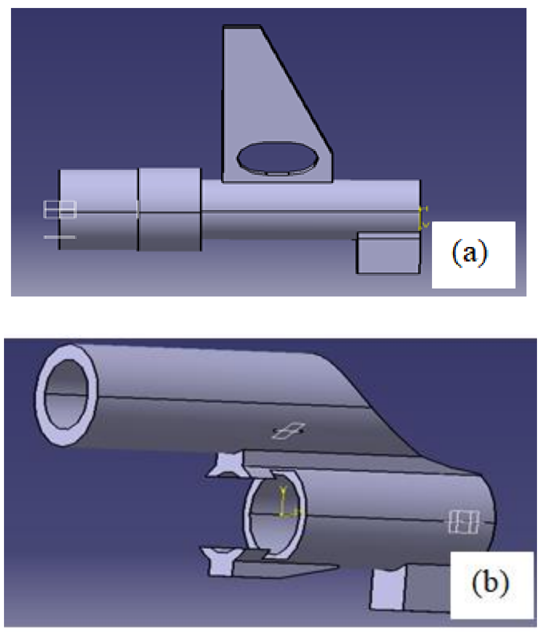
3.2. Design of New Assembly Process Layout

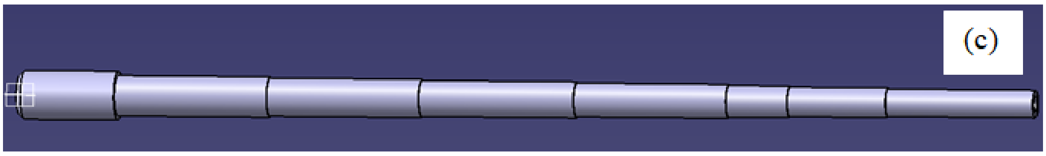
The tool used to design process layout is depicted in flow diagram. In the assembly factory, 54 parts are received from manufacturing factories (investment casting factory and machining factory).

In design of assembly process layout, methods factors such as; capacity of current available equipments, revising of the existing assembly system, time taken for assembly in each process, long time taking process, cause of problems and recommended solutions covered , and new assembly process layout flow diagram is designed.

Having the above considerations, (1) Design of process layout (2) Setting recommendations on improvements of equipment and labor allocation for each stage of assembly line and (3) Analyzing the improvement in terms of cost and assembly time activities were held in improving productivity of assembly.

3.2.1. Drawing: Integrated components drawing was sketched and prepared using CATIA V5. CATIA drawing of separate and integrated components are shown in Fig. 1.





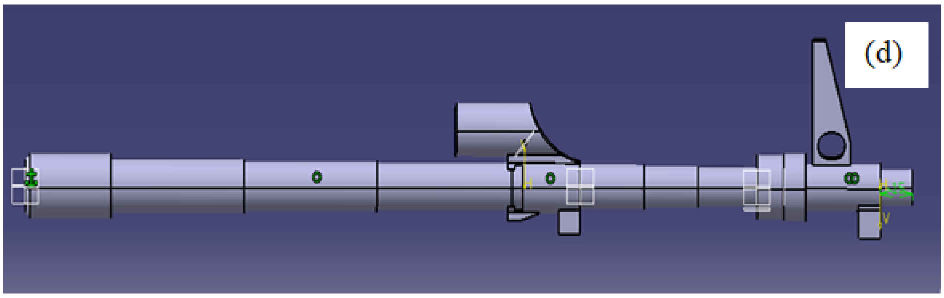


Figure 1: CATIA drawing of separate and integrated components (a) Foresight, (b) gas chamber and (c) barrel (d) integrated

The 53 components received from machining factory should be inspected in first stage of assembly sub grouped in to three groups. These components have to be stored near to assembly line according to the need in assembly line. The 53 components received from manufacturing factories are shown in Table 1 given below.

Table 1: The 53 components received from manufacturing factories

No.	Part name	Part code
1	Barrel	11-10
2	Ass. receiver body	Ps11-10
3	Muzzle brake	29-1c
4	Rear sight base	11-21
5	Gas chamber	11-29
6	Foresight base	11-30
7	Piston frame	13-1
8	Piston rod	13-2
9	Ass. Bolt	Ps3-2
10	Barrel peg	11-48
11	Ass. For end ring	Ps11-11
12	Eye bolt	1-42
13	Sight leaf	22-1a
14	Foresight pin	1=32
15	Gas chamber pin	1-33
16	Rear sight base peg	1-34
17	Upper hand guard lock	Ps1-6
18	Magazine catch pin	10-13
19	Piston rod pin	Ps3-3
20	Hammer	0-2
21	Trigger	0-8
22	Sear	0-9
23	Hammer pin	0-25y
24	Muzzle brake spring pin	20-26
25	Muzzle brake pin	20-22
26	Ass. Operating rod	Ps14-1
27	Operating rod collar	14-14
28	Receiver cover rivet	0-22
29	Grip fixing bolt	10-19
30	Screw driver	2-1
31	Oiling brush	Yps15
32	Cleaning rod	10-24
33	Ass. Blade	Ps20-34
34	Butt stock screw	5-14
35	Sight leaf spring	0-23
36	Ass. Upper hand guard	Ps11-12y
37	Magazine catch	10-11y
38	Magazine catch spring	0-12
39	Hammer spring	0-3
40	Safety sear	0-5
41	Safety sear spring	0-6
42	Sear spring	0-10
43	Muzzle brake spring	11-38
44	Return spring	4-3
45	Operating rod front part	14-5
46	Receiver cover	10-1y
47	Receiver cover catch	20-21
48	Muzzle cup	Yps1-1
49	Acc. Case	Y1-1
50	Ass. Magazine body	Ps17-1
51	Butt stock	b-25
52	Lower hand guard	Ps16-1a
53	Ass. Hand grip	Ps-18

Grouping of all components for group 1, 2 and 3 assemblies are shown in Table 2 given below.

Table 2: Grouping of the components

Components of group 1 assemblies

No.	Part name	Part code
1	Barrel	11-10
2	Ass. receiver body	Ps11-10
3	Rear sight base	11-21
4	Gas chamber	11-29
5	Foresight base	11-30
6	Barrel peg	11-48
7	Ass. For end ring	Ps11-11
8	Sight leaf	22-1a
9	Upper hand guard lock	Ps1-6

Components of group 2 assemblies

No.	Part name	Part code
1	Piston frame	13-1
2	Piston rod	13-2
3	Foresight pin	1=32
4	Gas chamber pin	1-33
5	Rear sight base peg	1-34
6	Magazine catch pin	10-13
7	Piston rod pin	Ps3-3
8	Butt stock screw	5-14
9	Sight leaf spring	0-23
10	Ass. Upper hand guard	Ps11-12y
11	Magazine catch	10-11y
12	Magazine catch spring	0-12

Components of group 3 assemblies

No.	Part name	Part code
1	Hammer	0-2
2	Trigger	0-8
3	Sear	0-9
4	Hammer pin	0-25y
5	Muzzle brake spring pin	20-26
6	Muzzle brake pin	20-22
7	Ass. Operating rod	Ps14-1
8	Operating rod collar	14-14
9	Receiver cover rivet	0-22
10	Grip fixing bolt	10-19
11	Screw driver	2-1
12	Oiling brush	Yps15
13	Cleaning rod	10-24
14	Ass. Blade	Ps20-34
15	Hammer spring	0-3
16	Safety sear	0-5
17	Safety sear spring	0-6
18	Sear spring	0-10
19	Muzzle brake spring	11-38
20	Return spring	4-3
21	Operating rod front part	14-5
22	Receiver cover	10-1y
23	Receiver cover catch	20-21
24	Muzzle cup	Yps1-1
25	Acc. Case	Y1-1
26	Ass. Magazine body	Ps17-1
27	Butt stock	b-25
28	Lower hand guard	Ps16-1a
29	Ass. Hand grip	Ps-18
30	Ass. Hand grip	Ps-18

3.2.2. Process layout: Process flow layout of assembly for AK-103 is shown in Fig. 2 given below

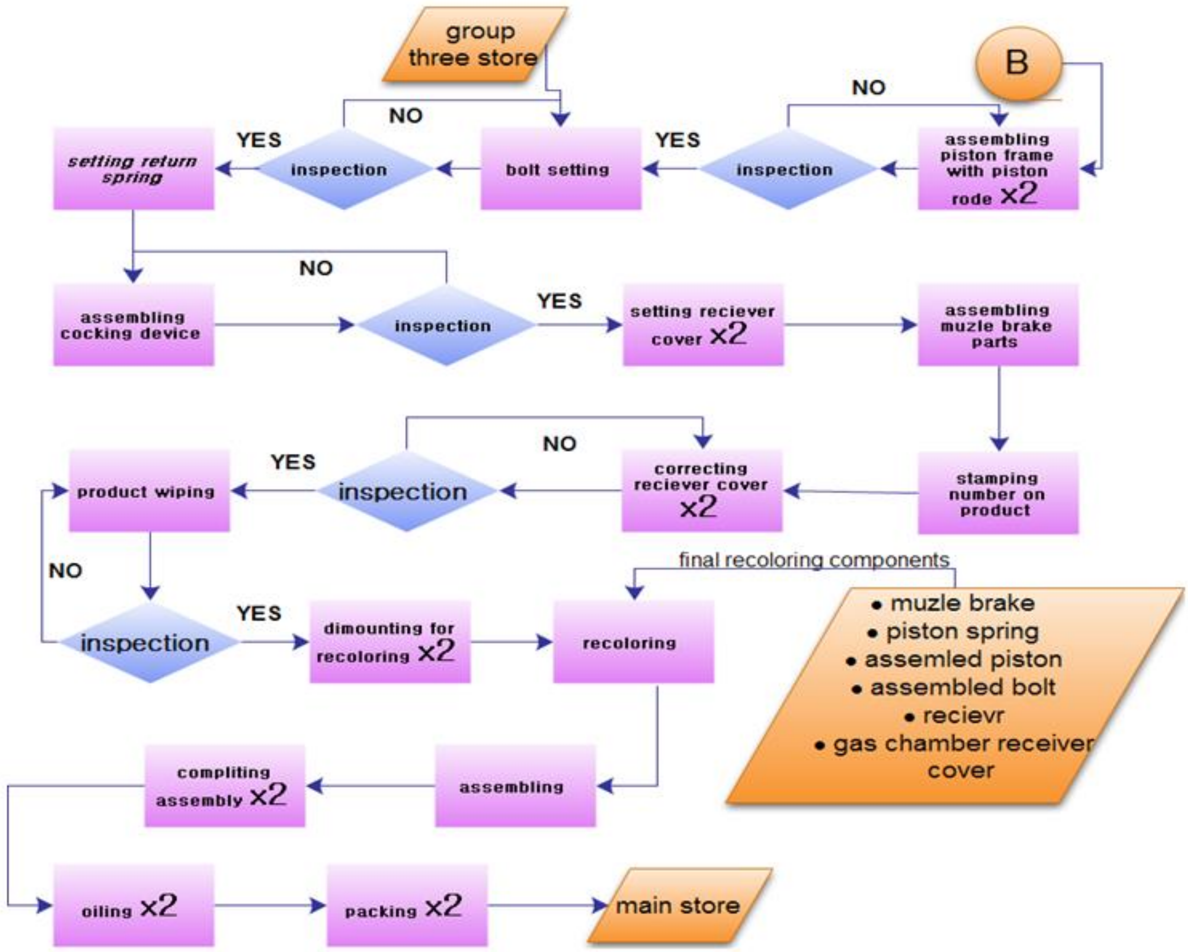


Figure 2: Process flow layout of AK-103 assembly

3.3. Design of Jigs and Fixtures to Increase Productivity in Assembly of Components

Jigs and fixtures are very important to minimize the difficulty and they are necessary in assembly factory. The controlling mechanism of barrel and breech block assembly and spring loader is also used.

The control mechanism was developed due to problem started is in current assembly system. The problem was that when assembling barrel and breechblock by force fitting using horizontal hydraulic machine, they could not show where it is reaching. Because the assembly of barrel and receiver is covered by fixture of hydraulic force fitting machine.

In GAI, the jigs and fixtures found in the factory are inefficient. Efficiency of jigs and fixtures can be improved using available materials and for this two jigs are designed and manufactured. Both jigs are served in assembly of barrel and receiver. These two jigs will also have their own contribution in minimizing the problems in assembly of barrel and receiver. The current assembly system of barrel and breechblock is shown in Fig. 3 given below.

Figure 3: The current assembly system of barrel and breechblock

3.3.1. Design of Spring Loader for Cartridge Motion Testing

To design the spring, the light load application (15 kg) and available in industry, the material selected for spring is music wire with diameter of 2.63 mm and maximum shear stress 490 MPa for average service were considered. CATIA drawing of the assembly of loader is shown in Fig. 4 given below.

Parameters mechanism of spring selection such as; (1) Maximum deflection is the motion of cartridge motion tester that is 130mm (2) The weight or load is taken from manual and the figure value is 15 kg (3) The cross sectional diameter of the wire is 2.63 mm and (4) internal diameter to be 12mm, the external diameter will 14.63mm were considered.

Considering the data in design, the spring is manufactured in the factory. Then heat treated and made to have recommended property. The case is manufactured as it is shown in the Fig. 4 given below. The working process of the loader is as follows.

1) The number loader and base are connected with telescopic road and spring
2) The base is fixed and the loader is moveable
3) The loader is pulled with two hands
4) It is positioned in the way that the lower extended base connecting the tester
5) The pulled loader is released so that to pull the tester with the desired 15 kg in its position by using pre extended spring in order to be compressed.

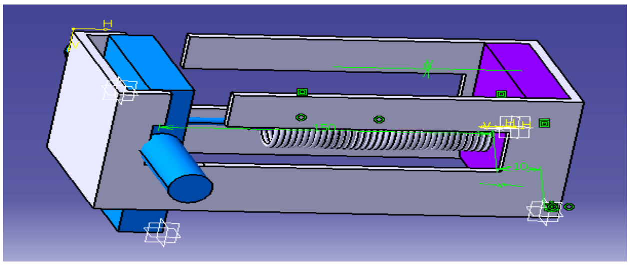


Figure 4: CATIA drawing of the assembly of loader

After manufacturing the spring it is tested with suspending the 15kg weight. Then the spring is extent ended for 110 mm. so the building of the case is started depending on that length. Spring loader for testing is shown in Fig. 5 given below.

Figure 5: Spring loader

Figure 6: Loader on testing

The loader was tested by fixing it with the table of fixture, then pulling it to the distance of 110mm that come from testing of the 15 kg. The loader plate and loading fixture made to be connected. Then realizing the pre extended spring result the desired load. Loader on testing physically handled by operator is shown in Fig. 6 given above.

3.3.2. Design of controlling mechanism for the range of force fitting distance of barrel and receiver

Controlling mechanism of force fitting is designed and followed by three mechanisms. Controlling assembly of hydraulic force fit is shown in Fig. 7 given below.

The materials used in this mechanism ware (a) Digital caliper that is numbered with (2) for slider and (1) for digital displayer (b) Moving rod is numbered with (5) (c) Fixed bas is numbered with (3) and (d) Support is numbered with (4)

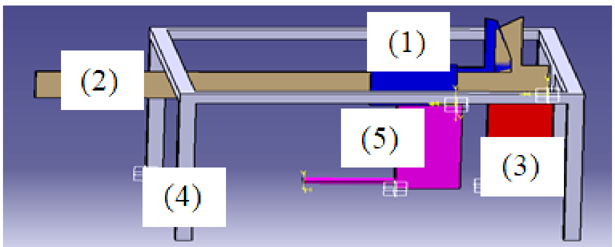


Figure 7: CATIA drawing of hydraulic force fit

Figure 8: Controlling mechanism

The working principle for the fitting distance indicator is in the following manner.

The caliper is set to zero. The hydraulic machine is started to push the barrel to be fitted in receiver. So the digital displayer of the caliper will be moved reading the distance. After the digital displayer reach at the desired position the foot on the power on will be raised. Controlling mechanism of digital displayer is shown in Fig. 8 given above.

The testing of the control mechanism was done by connecting the end of locator with barrel edge inside breechblock and then the caliper is set to be zero. The hydraulic press machine is started. The caliper was moved in the direction of barrel motion reading the distance it was pushed by barrel. The system of controlling mechanism is shown in Fig. 9 given below.

Figure 9: The controlling mechanism loader on testing

3.3.3. Study of the total time needed for each assembly process

The time needed in each process is taken from the factory and checked by using timer clock. Beginning from this known data the annual capacity of the factory is estimated by introducing standard continuous assembly system by assigning the workers in each process. Study was made on 234 samples at different time for different purpose.

The capacity of the factory was estimated followed by considerations such as; (a) Seven out of eight working hours are considered as active working time (b) One hour is given for cleaning and other purpose (c) 16 days are given to national days (d) 104 days of week end are also considered as rest.

3.3.4. Integrating parts and components to reduce assembly time and cost

To integrate the components it is necessary to analyze the components of AK 103 with the three considerations of design for assembly.

The methods used for this part of research are listed (a) Analyzing the machining processes for the parts in time of separated and integrated, and (b) CATIA software was used to model the integrated part.

3.3.5. Identifying cause of cracks during assembly

Frequent cracking of parts during assembly will have significant effect on the overall productivity of assembly. It will result in wastage of time and material. Hence, identifying the real cause of crack in parts is very important. The crack detection methods were mainly used (a) Inspection of parts at different steps of the process (b) Investigation of heat treatment of parts.

3.3.6. Inspection of parts at different steps of the process

Magnetic crack testing mechanism is used to inspect crack at different level at Dejen Aviation. This is the method by which bearings of aircraft are inspected in the company. Taking samples from components that are in machining, heat treatment, coloring, assembly and recoloring; crack detection testing is performed. Samples are selected in the processes randomly. Components for magnetic crack testing were taken are shown in Fig. 10 given below.

Figure 10: Components for magnetic crack testing

3.3.7. Effect of assembly system on cause of crack

Effect of assembly equipment that could be resulted due to vibration of drilling machineries and problem on force fit. The test was conducted for the components to be checked conditioned by (1) if hardness is in the recommended range (2) the components are checked if there was no defects or cracks (3) assembly process is conducted on the components , and finally the components are checked if there is crack due to assembly process are they if any.

In addition to that the dimensions of male and female parts are checked if they are not out of standards. The desired dimensions are taken from manual. Three samples are selected by random method. Measuring of the internal diameter for female and external diameter for male components is taken by using digital caliper. Then deviation of measured value is compared to deviation of manual value.

4. Results and Discussion

4.1 Problems and cause of problems for Equipment and Labor allocation for each stage of assembly line

In current assembly system, there are different problems at different stages. The problem of crack in foresight gas chamber and breechblock is also discussed. The time indicated in bracket shows the improvement of assembly time by applying the recommended solutions.

Barrel and receiver assembly (20-5 min)

In GAI there was four group of barrel was manufacturing. The main difference of different group barrel was difference in geometry. Group manufacturing system of barrel result problem in interchangeability in assembly time. This group manufacturing system was avoided and identical interchangeable barrel is made to manufactured. Two jigs will help to minimize the number of problems in barrel and receiver assembly. Barrel and receiver assembly picture is shown in Fig. 11 given below.

Observed Problems

There are four problems observed in bareel and recover assembly section and namely they are; (1) difficult of assembling barrel and receiver on their correct positioning (2) Barrel and receiver is often idle due to man power (3) Barrel and receiver fitting machine have problem of stacking and providing needed force and, (4) problem on accuracy of barrel and receiver products.

Figure 11: Barrel and receiver assembly

Causes of problem

The reason for the problems are raised such as;(1) accuracy in barrel and receiver (2) The machinery for force fitting of barrel and receiver has problem and the workers that are assigned in this area often leave the work and it result the assembly system to be idle for long period of time (3) The machine on the assembly has internal maintenance problem.

Receiver body & barrel fixing pin (20 – 5 min)

Observed Problems: Problems observed during fixing pin are such as; (1) Breech block and receiver body is assembled by pin. The pin hole is pierced by drill. The pin is assembled by force fit and at this time breech block is often cracked, and (2) the pin is large.

Causes of the problems

There two causes for breech block crack are; (1) The machine using for drilling shows vibration sign due to long time working and it is difficult to position center in the time of drilling (2) Breech block is not in its HRC when it comes from machine shop, and (3) tolerance and accuracy problem in the assembly parts.

a. Lock and rear sight frame (10-5 min)

Observed Problems: Problems observed in sight frame and they are namely; (1) Lock and rear sight assembly machine is not working (2) Crack on rear sight base.

Causes of problem

Two problems were raised and these are namely such as: (1) The machine has maintenance problem (2) The product has not desired HRC

b. Foresight frame and gas chamber for fixing pin (20-5 min)

Problems

There are couple of problems observed in sight frame and gas chamber and those are such as; *(1)* Problem of keeping the center when we pierce due to vibration of the machinery (2) Jig problem of the machinery (3) drill bit problem (4) After drilling there is need of pin insertion for foresight and gas champers *(5)* problem on pins accuracy *(6)* Cracking problem when foresight and gas champers are pierced and *(7)* cracking at the time of pin insertion

Causes of problem

The cause of problems are counted and they are namely such as; (1) vibration problem on the machinery (2) problem on jigs due to long time service (3) Break down of drill bit is the main problem and to take out the broken drill bit is time taking (4) The pin insertion is by man power and it is time taking and effort full process (5) Size of pin is much larger than drill bit, so that it difficult to force fit (6) In the time of piercing foresight frame and gas champers there is cracking problem and the cause for this problem is that the parts are not with desired HRC.

c. Sight leaf assembly (25-20 min)

Problem observed during sight leaf assembly was its boring and time taking to adjust sight leaf. *Cause of problem exactly* were human power adjustment is time taking and it needs large human power.

d. Piston assembly (15-7 min)

Observed Problems: Problems observed in piston assembly were *(1) Piston* carrying capacity either being large or smaller *(2)* If the metal is strong it is difficult the pin to penetrate, and (3)Pistons are not interchangeable

Cause of problem

Causes of problems were counted such as;(1) Production of piston is not in their desired specifications (2) The metals are beyond the desired HRC (3) If we can keep the specification of piston, there will be increment in interchangeability of piston.

e. Bolt setting (30-5 min)

Prepared drawing of bolt using CATIA software is shown in Fig. 12 given below.

Observed Problems: Four problems were observed during bolt setting and they are as:(1) problem of bolt to fit in its position (2) bolt has variability problem *(3)* problem on firing pin, and (4) problem on extractor

Causes of problem

During the bolt stetting causes arise were counted and they are; *(1)* bolt have very complex geometry the cause of problem in the desired criterion (2) bolts are not uniform when they are produced (3) The basic problem on firing pin is that there is not drill bit for that hole, and *(4)* problem of extractor is that it is made manually.

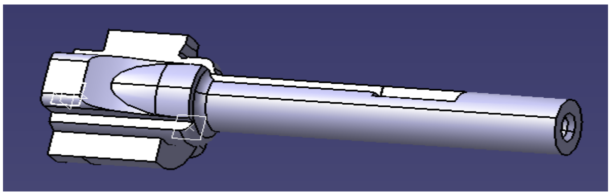


Figure 12: CATIA drawing of bolt

4.2. Identifying cause of cracks during assembly

The parts that are wasted due crack are foresight, gas chamber and breech block. There is no crack inspecting equipment in processes. Here are photographs of often cracking components of AK103. They are gas chamber, breech block and foresight (left to right). Components with frequent cracks during assembly are shown in Fig. 13 given below.

Figure 13: Components with frequent cracks during assembly

Taking the pieces from machining, heat treatment, coloring, assembly and recoloring processes the test of crack detection was conducted on the components using magnetic crack testing mechanism. Crack detection result which is obtained for the components from different processes is shown in Table 3 give below.

Table 3: Result of crack detection for the components from different processes

Type of components	Level of process	Total number of pieces	number of Crack detected pieces	remark
Foresight base	machining	8	0	
Gas chamber	machining	8	0	
Breech block	machining	8	0	
Foresight base	Heat treatment	8	2	
Gas chamber	Heat treatment	8	1	
Breech block	Heat treatment	8	1	
Foresight base	coloring	8	2	
Gas chamber	coloring	8	1	
Breech block	coloring	8	2	
Foresight base	assembly	8	3	
Gas chamber	assembly	8	1	
Breech block	assembly	8	2	
Foresight base	recoloring	8	4	
Gas chamber	recoloring	8	2	
Breech block	recoloring	8	3	

As we can see from table result of crack test the most cracking piece is foresight. Coloring is the process in which most crack is observed. In machining no problem is observed. In fact the stress concentration in previous process can be cause of crack in assembly and recoloring.

4.3. Investigation of heat treatment of parts

Crack detecting components by hardness testing are shown in Table 4 given below.

Table 4: Result of Rockwell hardness testing for crack detected components

Type of components	Total number of pieces	number of pieces out of HRC result	Range of Rockwell
Fore sight	8	5	35-42
Gas chamber	8	3	35-42
Breech block	8	4	37-44

As it can be observed from table half of the crack defected, pieces are out of recommended Rockwell hardness values. Therefore, half of the crack problem is due to problem on heat treatment or inability of keeping recommended hardness value.

As it is surveyed the heat treatment process, there are main problems in keeping manual instructions. So the problem of cracking of the components starts at this stage.

4.4. Investigation of alkaline coloring process

To observe effect of chemical on cracking of the components, statistical test was conducted in recoloring process. The following result was obtained. Effect of recoloring process on cracking of the components are shown in Table 5 given below.

Table 5: Effect of recoloring process on cracking of the components

Component type	Number of components tested	Number of components crack detected
Fore sight	20	8
Gas chamber	20	5
Breech block	20	7

From the statistical data results, about 50 % cause of crack is due to problem in heat treatment. Based on statistical experiment made on coloring process, 33% cause of crack is due to effect of different chemicals in coloring process on stress concentrated components. From the experiment made in assembly process, 10% cause of crack is the problem in current assembly process and the rest 7% cause of crack is due to unknown problem on which test cannot be held.

4.5. Study of the total time needed for each assembly process

The processes are assembly of barrel and receiver, assembly of lock and rear sight frame, sight leaf assembly, adjustment of aiming line, adjustment of gas chamber position, drilling fixing pin hole for rear sight frame, drilling fixing pin hole for gas chamber, setting fixing pin, machining gas hole, fore end assembly, assembly of magazine catch, assembly of piston frame, bolt setting, assembly of cocking device, setting receiver cover, stamping number of products, correcting receiver cover, disassemble the rifle, cleaning the rifle, assembly of the rifle and packing of the product. Therefore, there is a need of improvement this processes. Total Time taken for assembly of AK 103 is shown in Table 6 given below. There are three symbols in table and the meaning of the symbols is depicted below.

A = Current Finishing time (min), **B =** total pieces processed/year in one shift, **S/N** = serial number

Detailed result of improvement for assembly time for forty six processing's enlisted in Table 6 given above. As it can be seen in the below Table, the annual capacity of all assembly steps are 20580 and above. Therefore, the minimum annual capacity for improved system is less than the planed 30,000. Annual assembly capacity of improved system is shown in Fig. 14.

Table 6: Time taken for assembly of AK 103

S/N	Process name	A	B
1	Barrel & receiver ass.	20	5145
2	Recording on certificate	1	102900
3	Stamping on receiver	5	20580
4	Machining fixing pin hole	5	20580
5	Fixing pin ass.	3	34300
6	Grooving for extractor	5	20580
7	Ass. Lock &ass. rear sight frame	10	10290
8	Ass. Gas chamber & for end ring	5	20580
9	Adj. Gas chamber position	10	10290
10	Sight leaf assembly	25	4116
11	Adj. Aiming line	15	6860
12	Ass. Foresight base	2	51450
13	Correcting foresight base	5	20580
14	Amending barrel with long gauge	2	51450
15	Drilling fixing pin hole for rear sight frame	6	17150
16	Drilling fixing pin hole for gas chamber	10	10290
17	Setting fixing pin	20	5145
18	Amending unsatisfied product	5	20580
19	Assembling. Assembled upper hand guard	5	20580
20	Writing product no	5	20580
21	Machining gas hole	12	8575
22	Debarring on gas hole	2	51450
23	Dismounting before coloring	5	20580
24	Coloring& inspecting	5	20580
25	Receiver wiping &setting change lever	5	20580
26	Ass. sight leaf &upper hand guard	5	20580
27	Replacing sight leaf	3	34300
28	Butt stock ass.	5	20580
29	Butt stock fixing	5	20580
30	Finishing	3	34300
31	Fore end ass.	10	10290
32	Ass. Magazine catch	10	10290
33	Ass. Piston frame	15	6860
34	Bolt setting	30	3430
35	Replacing bolt after firing	5	20580
36	Setting return spring	3	34300
37	Ass. Cocking device	20	5145
38	Setting receiver cover	6	17150
39	Ass. Muzzle brake parts	5	20580
40	Stamping no. of products	10	10290
41	Correcting receiver cover	7	14700
42	Disassemble the rifle	7	14700
43	Coloring	2	51450
44	Cleaning the rifle	10	10290
45	Ass. The rifle	7	14700
46	Punch the hand grip	1	102900
47	Oiling	1	102900
48	packing	10	10290

4.6. Analysis of improvement on assembly time and cost

A. Improvement of time

By applying, the recommended solutions and the layout, there will be reduction of time. Improvement in assembly time is shown in Table 7 given below. Nomenclatures of the concepts on the table are listed below.

A: Current finishing time (min), **B:** total pieces processed/year in one shift, **C:** New Finishing time (min), **D:** Recommended number of assembly lines, **E:** total pieces processed per year, **F:** One line & one shift assembly process, **G:** Two line & one shift assembly process.

This graph from Fig. 14 shows the processes of assembly versus annual production capacity. The horizontal line in between 20000 and 40000 represents the plan of the industry that is 30000 annual production capacities. As it is shown in the above graph, most of the assembly processes are below the planed capacity that is 30000. There are some assembly processes near to zero line representing annual assembly productivity of about 500.

Table 7: Result of improvement for assembly time

S/N	Process name	A	B	C	D	E	
						F	G
1	Barrel & receiver ass.	20	5145	5	1	20580	41160
2	Recording on certificate	1	102900	1	1	102900	205800
3	Stamping on receiver	5	20580	5	1	20580	41160
4	Machining fixing pin hole	5	20580	5	1	20580	41160
5	Fixing pin ass.	3	34300	3	1	34300	68600
6	Grooving for extractor	5	20580	5	1	20580	41160
7	Ass. Lock &ass. rear sight frame	10	10290	5	1	20580	41160
8	Ass. Gas chamber & for end ring	5	20580	5	1	20580	41160
9	Adj. Gas chamber position	10	10290	5	1	20580	41160
10	Sight leaf assembly	25	4116	20	4	20580	41160
11	Adj. Aiming line	15	6860	5	1	20580	41160
12	Ass. Foresight base	2	51450	2	1	51450	102900
13	Correcting foresight base	5	20580	5	1	20580	41160
14	Amending barrel with long gauge	2	51450	2	1	51450	102900
15	Drilling fixing pin hole for rear sight frame	6	17150	6	2	34300	68600
16	Drilling fixing pin hole for gas chamber	10	10290	5	1	20580	41160
17	Setting fixing pin	20	5145	5	1	20580	41160
18	Amending unsatisfied product	5	20580	5	1	20580	41160
19	Assembling. Assembled upper hand guard	5	20580	5	1	20580	41160
20	Writing product no	5	20580	5	1	20580	41160
21	Machining gas hole	12	8575	12	3	25725	51450
22	Debarring on gas hole	2	51450	2	1	51450	102900
23	Dismounting before coloring	5	20580	5	1	20580	41160
24	Inspecting colored components	5	20580	5	1	20580	41160
25	Receiver wiping &setting change lever	5	20580	5	1	20580	41160
26	Ass. sight leaf &upper hand guard	5	20580	5	1	20580	41160
27	Butt stock ass.	5	20580	5	1	20580	41160
28	Butt stock fixing	5	20580	5	1	20580	41160
29	Finishing	3	34300	3	1	34300	68600
30	Fore end ass.	10	10290	10	2	20580	41160
31	Ass. Magazine catch	10	10290	5	1	20580	41160
32	Ass. Piston frame	15	6860	7	2	29400	58800
33	Bolt setting	30	3430	5	1	20580	41160
34	Setting return spring	3	34300	3	1	34300	68600
35	Ass. Cocking device	20	5145	5	1	20580	41160
36	Setting receiver cover	6	17150	6	2	34300	68600
37	Ass. Muzzle brake parts	5	20580	5	1	20580	41160
38	Stamping no. of products	10	10290	10	2	20580	41160
39	Correcting receiver cover	7	14700	7	2	29400	58800
40	Disassemble the rifle	7	14700	7	2	29400	58800
41	Inspecting Colored pieces	2	51450	2	1	51450	102900
42	Cleaning the rifle	10	10290	10	2	20580	41160
43	Ass. The rifle	7	14700	7	2	29400	58800
44	Punch the hand grip	1	102900	1	1	102900	2058000
45	Oiling	1	102900	1	1	102900	205800
46	packing	10	10290	10	2	**20580**	**41160**
					61		

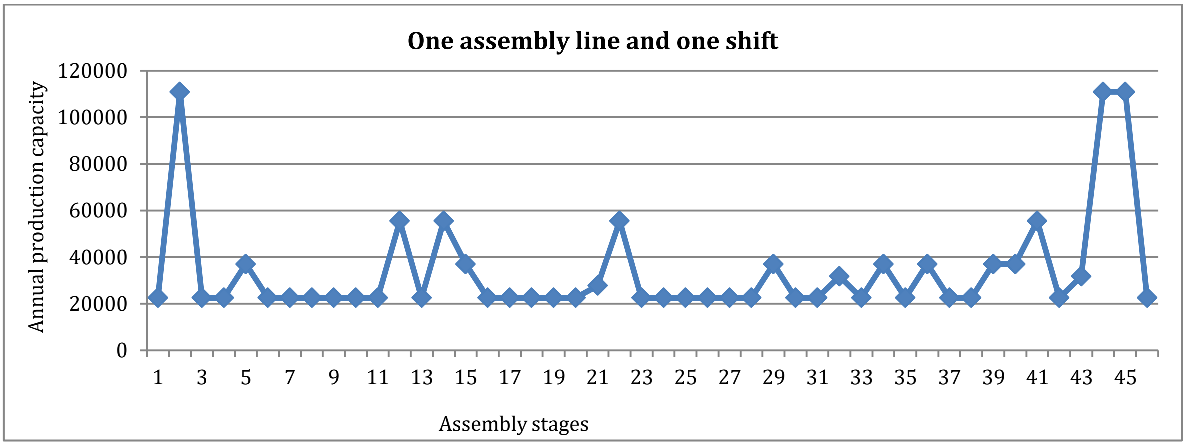


Figure 14: Annual assembly capacity of improved system

To test the assembly process layout needs 61 workers. The test was performed on the assembly stages. The operator finished time was all less than the specified time.

B. Improvement of assembly cost

The number of workers in assembly factory is 24. The annual payment for salary of the workers is 314640 ETB. Therefore, average annual payment for one worker is 13110 ETB. The number of workers needed to work the factory in all its capacity without improving the recommended works and the designed process layout is 48. However, in new improved system of assembly, the required number of workers is 61.

Taking the stage that needs longest time (bolt setting needs 30 min) for old assembly system, the annual capacity of the factory is 3430. Taking the stage that needs longest time that is 5 min for improved assembly system, the annual capacity of the factory is 20580.

The productivity is of the old assembly system is 71.5 piece per single worker per year. But the productivity is of improved assembly system is 327 piece per single worker per year.

The productivity in terms of cost considering annual salary of the workers, assembly cost for one piece in old system is 183 ETB. But in improved system is 39 ETB.

In assembly of the Kalashnikov there are different accessories to be used. The accessories equipments of assembly factory and their respective cost are listed in Table 8 given below.

Table 8: Equipment and their cost in assembly factory

Item	Description	Model	Make	Location	Qty	cf	Grc(Birr)	Drv(birr)	203 Dep.Value
1	bench drilling	1--12	D.P.R.K	8.A--1--1	1	0.45	6000	2700	270
2	hydro power press	TON5-CC	ITALY	8.A--1--2	1	0.5	15000	7500	750
3	2spindle pedestal drilling	TRAPANI ROSA	ITALY	8.A--1--3	1	0.5	30000	15000	1500
4	polishing	71--800	D.P.R.K	8.A--1--4	1	0.5	8000	4000	400
5	2spindle pedestal drilling	TRAPANI ROSA	ITALY	8.A--1--5	1	0.5	30000	15000	1500
6	1spindle bench drilling	1--12	D.P.R.K	8.A--1--6	1	0.45	6000	2700	270
7	Tool grinding	200-1	D.P.R.K	8.A--1--7	1	0.5	12000	6000	600
8	3spindle bench drilling	3--12	D.P.R.K	8.A--1--8		0.45	16000	7200	720
9	3Spindle bench drilling	3--12	D.P.R.K	8.A--1--9	1	0.45	16000	7200	720
10	horizontal oil press	10	D.P.R.K	8.A--1--10	1	0.45	30000	13500	1350
11	disassembly m/c	11--7	D.P.R.K	8.A--1--11	1	0.45	30000	13500	1350
12	horizontal oil press m/c	10	D.P.R.K	8.A--1--12	1	0.1	30000	3000	300
13	horizontal oil press m/c	10	D.P.R.K	8.A--1--13	1	0.45	30000	13500	1350
14	horizontal oil press m/c	10	D.P.R.K	8.A--1--14	1	0.45	30000	13500	1350
15	keyway milling	KIRLOSKARVAD I	INDIA	8.A--1--15	1	0.5	30000	15000	1500
16	2Spindle pedestal drilling	Tranpani ROSA	ITALY	8.A--1--16	1	0.45	30000	13500	1350
17	pistion assembly	43-1	D.P.R.K	8.A--1--17	1	0.45	10000	4500	450
18	buff grinding	9-300	D.P.R.K	8.A--2--1	1	0.5	12000	6000	600
19	2Spindle bench drilling	1--12	D.P.R.K	8.A--2--2	1	0.4	12000	4800	480
20	pistion frame assembly	13-1	D.P.R.K	8.A--2--3	1	0.6	10000	6000	600
21	barrel cleaning	3	D.P.R.K	8.A--2--4	1	0.5	30000	15000	1500
22	polishing	71-2-564	D.P.R.K	8.A--2--5	1	0.5	8000	4000	400
23	polishing	71-2-440	D.P.R.K	8.A--2--6	1	0.5	8000	4000	400
24	polishing	71-2800	D.P.R.K	8.A--2--7	1	0.5	8000	4000	400
25	oil pressing	10	D.P.R.K	8.A--2--8	1	0.45	30000	13500	1350
26	disassembly m/c	48-1	D.P.R.K	8.A--2--9	1	0.5	30000	15000	1500
27	compressed jig		D.P.R.K	8.A--2--10	1	0.65	10000	6500	650
28	pantho-graph(copying)	4-Jul	D.P.R.K	8.B--1--1	1	0.6	15000	9000	900
29	4Spindle bench drilling	12-Apr	D.P.R.K	8.B--1--2	1	0.45	22000	9900	990
30	pedestal drilling	VS-32B	U.S.S.R	8.B--1--3	1	0.6	18000	10800	1080
31	hydro power press	Ton.25-CC	ITALY	8.B--1--4	1	0.6	35000	21000	2100
32	circular grinding	71-200	D.P.R.K	8.B--1--5	1	0.55	10000	5500	550
33	tool grinding 9polisher)	200-1	D.P.R.K	8.B--1--6	1	0.55	8000	4400	440
34	buff grinding	9-300	ITALY	8.B--1--7	1	0.55	12000	6600	660
35	buff grinding	9-250	D.P.R.K	8.B--1--8	1	0.55	12000	6600	660
36	copy milling	Mohu-105	D.P.R.K	8.B--1--9	1	0.6	350000	210000	21000
37	manual press		D.P.R.K	8.B--1--10	1	0.65	5000	3250	325
38	Hoiste	RV2.1		8.B--1--11	1	0.4	10000	4000	400
Total								527150	

There are 38 machines (shown in Table 8 given above) and equipments in assembly factory. Each machineries and equipments, there is coefficient factor (cf) given to the accessory based on the current capacity of the accessory. So taking the dry value and average of 15 years life time for the current assembly system and 5 years for improved system, the component assembly cost due to the accessory it used to be assembled is estimated as follows. 30% of their dry value is assumed cost of maintenance of the equipments.

The assembly cost due to the equipment for current system

Total components to be assembled in average life time = 51450

Assembly cost due to the equipment value = sum of dry cost/total components assembled

Assembly cost due to the equipment value = 13ETB

The assembly cost due to the equipment for improved system

Total components to be assembled in average life time = 102900

Assembly cost due to the equipment value = sum of dry cost/total components assembled

Assembly cost due to the equipment value = 7 ETB

Cost of power consumption has also considered. There is not separated controller of power in assembly factory. The power controller of assembly room is with some part of machining factory and administrative office. Therefore, the average monthly power consumption for assembly room has taken as 40 % of total reading. The average monthly reading to assembly average of 190 components is 33554 ETB (Ethiopian Birr).

Power consumption = 13422

Cost of single component due to power consumption = 71 ETB

So total assembly cost for current system is = 267 ETB

Total assembly cost for improved system is = 116ETB

Conclusions

The parts that are wasted due crack are foresight, gas chamber and breech block. Result of crack test result confirms the most cracking piece is foresight. Coloring is the process in which most crack is observed. In machining no problem is observed. In fact the stress concentration in previous process can be cause of crack in assembly and recoloring.

Total time taken from entrance to exit for the components in assembly factory using current assembly process is 365 minutes. From this time, there will be reduction of 93 minutes by introducing the designed process assembly layout. There will be also reduction of 108 minutes of assembly time by improving the recommended manufacturing systems, assembly equipments and facilities.

Result of improvement for assembly time confirms that the annual capacity of all assembly steps are 20580 and above. Minimum annual capacity for improved system is less than the planed 30,000. Taking the stage that needs longest time (bolt setting needs 30 min) for old assembly system, the annual capacity of the factory is 3430. Taking the stage that needs longest time that is 5 min for improved assembly system, the annual capacity of the factory is 20580.

The number of workers in assembly factory is 24. The annual payment for salary of the workers is 314640 ETB. Therefore, average annual payment for one worker is 13110 ETB. The number of workers needed to work the factory in all its capacity without improving the recommended works and the designed process layout is 48. However, in new improved system of assembly, the required number of workers is 61.

The productivity is of the old assembly system is 71.5 piece per single worker per year which was improved by 327 piece per single worker per year in new assembly system. The productivity in terms of cost considering annual salary of the workers, assembly cost for one piece in old system is 183 ETB, whereas for the improved system is 39 ETB. Annual production capacity will increase from 3430 to 20580.

Average Power consumption costs were also compared for current and improved assembly system. Power consumption assembly cost for current system 267 ETB is much higher than 116 ETB cost of improved system.

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