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By Using Simulation Technique Determining the Effects of Manual Doffing Process on the Machine Efficiency and Profitability of the Spinning Mills

A. Baki Engin
Haliç University, Engineering Faculty,
Department of Industrial Engineering,
Istanbul, Turkey

ABSTRACT

The doffing process defined as the removal of full spinning tubes by stopping the ring spinning machine and replacing it with the new ones, is one of the essential ring spinning processes. Although this process can be done automatically by specialized ring machines, even today it is still done manually in many cotton ring mills established at some important ring yarn producer countries such as India, Pakistan, and Turkey to avoid the cost of automatic doffing equipment. However, the manual doffing process can lead to quite a lot of yarn breaks affecting machine efficiency and production significantly. Here, we examined how and to what extent unwanted breaks affect the machine efficiency by using a simulation technique and performing economic analysis taking into account certain parameters of efficiency. Our data show that increased lambda values with the same doffing process breaks result in higher production and profit losses. We suggest that the decision on doffing automation should be made using break-even analysis projecting both cost of doffing breaks and automation.

Keywords: Multi machine assignment, machine interference, doffing, ring spinning machine efficiency, spinning and simulation

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1. Introduction:

A business should be able to estimate machine efficiency for various different circumstances. However, assessment of the efficiencies of machines either analytically or utilizing other methodologies excluding simulation technique is not easy due to machine interference problem. This problem encountered in industries including textile spinning and weaving industries stems mainly from multi-spindles or multiple machine assignments per operator.

Machine interference can be described as "consider the simple system consisting of *n* machines and *r* workers. Each machine operates for a period of time until it breaks or otherwise requires attention, at which point it is sent to the service facility. A worker there spends a period of time servicing the machine and then returns it to operation. If there are more machines than workers, n> *r*, it will occasionally happen that all workers are already busy when another machine needs service. Thus, this system is a simple example of what is referred to as the "*machine interference problem* or alternatively as the *machine repairman problem"* (Haque and Armstrong, 2007). Considerable literature exists on machine interference problems.

For a comprehensive review of literature, one can refer to the paper of Haque and Armstrong (2007) and the paper of Steck and Aranson (1985).

In general, the methods for machine efficiency estimation involving machine interference issues consist of a) formulas or tables, b) queuing theory or model approach, and c) simulation.

Due to the yarn breaks occurring in spinning machines at random, and the assignment of spindles to one operator is very high, simulation technique has been used to determine the efficiency of spindle or machines. The program used for this purpose was written by the author and the basic algorithm of that is given in (Engin, 2008 and 2009).

2. Materials and Methods

2.1 The spinning Process

Spinning is the process of creating a yarn (or thread, robe, cable) from various raw materials. Ring spinning machines are used in the textile industry to simultaneously twist staple fibers into yarn and then wind it onto a bobbin for storage. Yarn can be made of staple (short) fibers by any one of several techniques. The development of short fibers, or staple, into yarn, when stated in terms of basic manufacturing processes, is as follows: carding, combing, drafting, twisting, and winding. As the fibers pass through these processes, they are successively formed into lap, sliver, roving, and finally yarn (Corbman, 1983).

The three major processes for converting stable fiber to yarn are ring spinning, open-end spinning, and air-jet spinning. Ring spinning is the oldest of process and the one that currently is used to convert the greatest quantity of fiber to yarn. Ring-spun yarns might be cotton, wool, flax, staple length manufactured fibers, or blends of these fibers. They are available in the widest range of sizes and are found in every application in which spun yarns are used, including most apparel items, carpet face pile, carpet backing, upholstery, drapery and curtain fabrics, tents, and awnings (Hatch, 1993).

A bundle of parallel fibers (the roving) is fed to the attenuating or drafting zone. The difference in surface velocity of the front (faster) and back (slower) drafting rollers will attenuate the roving to a thinner strand of parallel fibers, under the control of the double aprons. The thin strand of parallel fibers emerging from the front rollers is then simultaneously twisted and wound onto a yarn package (i.e., cop) mounted on a driven spindle. The twisted thin strand of fibers, now called a yarn, is threaded through a traveler and a yarn guide and balloons out between these two elements during normal spinning. The twisted yarn is then wound onto the bobbin or yarn package (Tang at al., 2006).

Although there are some different spinning systems in the textile industry such as open-end, air jet, etc., in our study we focused on the cotton ring-spinning system as it is the most widely used spinning system in the world.

Before using the factor analysis, the Cronbach's Alpha reliability on the variables has been tested to see if there was a significant association amongst the variables.

2.2. The spindle and machine efficiency

In the textile industry, the machine efficiency is defined as a ratio of the actual production of a machine to the theoretical production of this machine for a certain time. This can be expressed by the Formula (1). Since the actual production of a machine is proportional to the running time of this machine, then the machine efficiency can also be described at the same time as shown in the Formula (2).

$$\text{Spindle efficiency}(E) = \frac{\text{Spindle productive time}\,(TC - TS)}{\text{Operator cycle time}\,(TC)} \ldots\ldots(2)$$

$$\text{Spindle efficiency}(E) = \frac{\text{Actual production}}{\text{Theoritical production}} \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

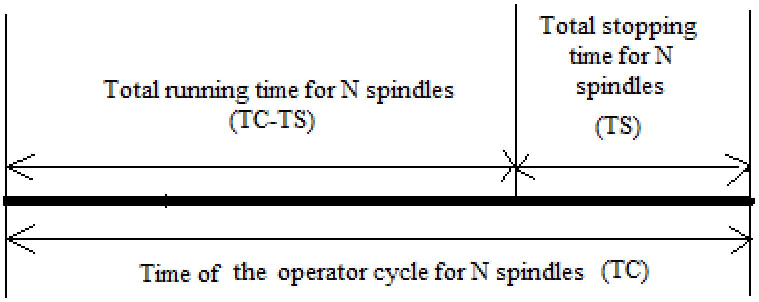

Figure 1. The illustration of the short term efficiency of spindles or machines which considers only end breaks stoppages time.

The theoretical efficiency of a machine for a certain time period can be described as the efficiency not including loss time due to any kind of stoppages. This means that the machine runs continuously in this period. However, in practice this is not possible as there are many inevitable stoppages such as ends breaks, doffing stoppages, machine maintenance, mechanical, and electrical- electronic failures. On the other hand, the actual efficiency of any machine in a certain time period takes into account all the machine stoppages. The efficiency illustrated by Figure 1 considers only end breaks stoppages. However, Figure 5 shown in section 2.6 depicts the total machine efficiency for a long-term period containing the short-term machine efficiency also. The efficiency estimated by means of the simulation program used in this work take into accounts only end break stoppages.

A spinning machine contains many identical spindles. Every spindle of a spinning machine can be considered as a small machine producing yarn. Therefore, the efficiency of a spinning machine will be equal to the efficiency of each spindles of the machine.

Figure 2. A view from ring spinning machines on which the roving bobbins and cops on the spindles are located.

In the case of all the machines are identical from all the point of working parameters, such as machine type and speed, article type and structure, and the care taken by operator and other personnel for all machines, the efficiency of the mill will be equal to the efficiency of each identical machine.

The machine efficiency calculations involving interference issues typically use four main parameters. These are;

1) The average of operator walking times of between machines
2) The average of mending or repairing times of machines by operator
3) The average of machine stoppages
4) The number of machines to be assigned per operator

However, in our work, taking into account the specific nature of the textile industry, we consider the following parameters in the determination of efficiency of spinning machines.

1) The average of operator walking times of between spindles
2) The average and distribution of mending times of ends breaks
3) The average and distribution of end breaks (stoppages)
4) The number of spindles to be assigned per operator
5) The service system of operator (determines which spindle or machine the operator should go to).

Here, operator walking time and ends breaks mending time is related to operator initiatives. However, the number of spindles, the service system of operator, the amount and distributions of ends breaks are under the responsibility of the management. Because end breaks frequency and its distribution depend on yarn material type and quality, count, twist, machine setting, speed and maintenance performance, environmental conditions such as humidity, temperature and vibrations which all falls under the responsibility of the department manager.

Generally, there are two different operator service systems in the textile industry. One of these systems is periodical operator service system and the other one is the random operator service system, which usually is applied in weaving mills.

In spinning mills, generally the periodical operator service system is implemented. Therefore, we consider a unidirectional periodical operator service system in our model due to the fact that it is more applicable in the textile industry. Figure 3 shows periodical operator servicing system and Figure 4 shows cops on the spindles.

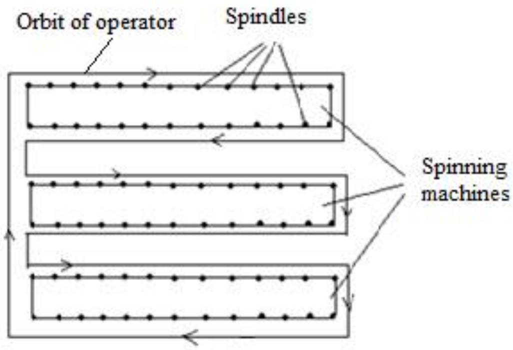

Figure 3. Ring machines and their periodical servicing cycle.

Figure 4. Unfilled cops on the spindles

2.3. Assumptions used in the model to estimate and analyze machine efficiency

1) The yarn breaks occur to according to a Poisson process with an intensity of occurrences per hour. In other words, the occurrence time of yarn breaks is described by exponential distribution which its mean will be shown with 1/ λ.
2) It is accepted that the operator average walking time of the distance between two spindles which is accepted as 75 mm was observed as 0,000035 hour and the operator mending time yarn breaks was observed as 0,0016 hour (Raja. R. and Rao. K. S. (2007).
3) The possibility of success in mending the all ends breaks is considered to be one hundred percent.
4) In our model, the tying of the broken yarn after the doffing process is done by the machine operator, and the doffers do not help.
5) In our model supposed that the mill considered is working 24 hours continuously.
6) Annual working day is 300.

2.4. Doffing process and its effect on the ring spinning machine efficiencies

The doffing process may be defined the replacement of full spinning tubes (cops) with empty ones which is implemented either by a group of doffing workers manually or by automatic devices. Also doffing performance can be defined as percentage of spindles that are producing after replacing the empty tubes. In this work, we analyze economic results of insufficient doffing performance which is faced in the manual doffing process. To explore the effect of doffing performance we consider five specific cases among the infinite cases to be faced. These are case 1 where the all spindles are productive, that is, no broken ends after completion of the doffing process, case 2 where 95 percent of spindles are productive, case 3 where 90 percent of spindles are productive, case 4 where 80 percent of spindles are productive and case 5 where 75 percent of spindles are productive. Case 1 is ideal situation but nearly impossible. For the reasons shown below, the ideal situation is moved away and the ideal situation can be approached to the extent that these problems are eliminated.

Some reasons of insufficient doffing processes are;

a. Lack of proper coordination of teams
b. Insufficient number of doffers
c. Lack of motivation of doffers
d. Shortage empty tubes
e. Delay in removal of full bobbins
f. Doffers are not qualified enough
g. Improper piecing of broken yarn during doffing
h. Insufficiently filled cops to start doffing
i. Breakage of yarn during removal of full cops and replacement of empty ones
j. Deformation of cops
k. Lack of machine maintenance (Raja. R. and Rao. K. S. (2007).

2.5. The calculation of yarn production

In the spinning industry production for per spindle in the time of one hour is calculated by means of the formula (3) shown below.

$$G(g/h) = \frac{0{,}9 \times n\,(rpm) \times EW(\%)}{Ne \times T''} \cdot \ldots\ldots\ldots\ldots(3)$$

Here :0, 9 is a constant
n: Spindle speed in revolutions per minute
EW(%) : Spindle or machine efficiency
Ne: English count of yarn
If yarn count is given in Nm
Ne = Nm × 0,591
Nm: Metric count of yarn
Nm = L(m) / G(g)
L(m): Length of yarn as meter unit
G(g): Weight of yarn as gram unit
Tm: Number of round on the one meter of yarn
T'': Number of turns per inch of yarn

$$T_m = T'' \times 39{,}37$$

EW (%): Weighted average efficiency of the spindle which is equal to the efficiency of machine for long time period.

We consider in our study a cotton ring spinning mill running three shifts per day and has 50 machines each with 1200 spindles and produces only 20 Ne count of yarn which has twist of 18, 5 tours / inch and 15000 rpm spindle speed. However, this consideration is nearly equivalent to producing different count of yarns which each have different twist of yarn depending on their counts only providing that their weighted average of counts is nearly 20 Ne and their weighted average of twist is nearly 18,5 and their weighted average speed is nearly 15000 rpm.

The production can be calculated for one spindle, one machine, all of machines, any efficiency and any period of time by the formula (3) given above. For example, the production for per hour of per spindle and for 100 % efficiency can be calculated as (0, 9 x 15000 x 100) / (20 x 18, 5) = 36,486 g/h.

2.6. Removal time of full cops and economic results of doffing performance

The removal time of full bobbins can be calculated as follows. If the maximum weight of the yarn on the cop is accepted as 150 g, then the theoretical filling time will be 150/36,486 = 4,11 h and the machine efficiency will be 100 percent. However, spindle efficiency will not be 100 percent any time due to various stoppages which have been mentioned before. After the machines run for 4,11 hours, it will be time to remove cops, but less than 150 g of yarn will be wound on the cops, depending on the spindle efficiency (because no yarn is wound on the cops until end breaks repaired although machines is working).

Tables 1, 2 and 3 show the weighted average efficiency values obtained in case of assignment 3600 spindles to one operators, a certain operator walking and end breaks repairing time considering different λ values, which also corresponds to one thousandth of end breaks per 1000 spindle hours in textile terminology. In these tables, λ = 0,050, λ = 0,100, λ = 0,150 values correspond to good, poor and worse quality of yarns respectively. These tables indicate that in long term working hours the doffing performance has no important effect on the spindle or machine efficiency. But this is not a realistic situation due to the necessary removal of full cops. For example, it is seen from Table 1 for λ = 0,050 weighted average spindle or machine efficiency is nearby 99 % for case 1,2,3,4, and even case 5. Also, Table 2 and 3 show that for λ = 0,100 and λ = 0,150 weighted average efficiencies are nearby 98 % and 94 % respectively in long term, that is, after 150 cycles which correspond to 45 h and 107 h respectively.

However, it can be easily seen from these tables that, when the machine uptime reaches 4.11 hours, which is the time of removal of the cops, considerable differences are observed in the weighted average efficiency values depending on the λ and doffing performance values. This has important economic consequences on an annual basis.

In Table 4 are shown the weighted average efficiency values and loss of profit obtained by considering λ = 0,050, 0,100 and 0,150 values and 100%, 95%, 90%, 80%, 75% performance degrees. Weighted average efficiency values given in Table 4 have been obtained for 4,11 working time from Table 1, 2, 3 and 4 by interpolation. In the efficiency values obtained in Table 1, 2 and 3 only yarn breaks were taken into account, and other stoppages such as doffing, machine failure, and machine maintenance were not taken into account. However, such stoppages are also taken into account in Table 4. We calculate the machine efficiency considered all type of stoppages time as bellow;

Doffing process time averagely: 10 min / 4,11 h ⇒ 0,167 h for every 4,11 h

Type of yarn chancing time averagely: 20 min/30 day ⇒ 0,002 h for every 4,11h

Periodical machine maintenance time averagely: 8 h/ 6 month ⇒ 0,008 h for every 4,11h

Other all small stoppages time averagely: 5 min/ 4,11 h ⇒ 0,084 h for every 4,11h
Total stoppages excluding end breaks stoppages averagely ⇒ **0, 261 h** for every 4,11 h

Not that these stoppages values may vary more or less depending on to mill.

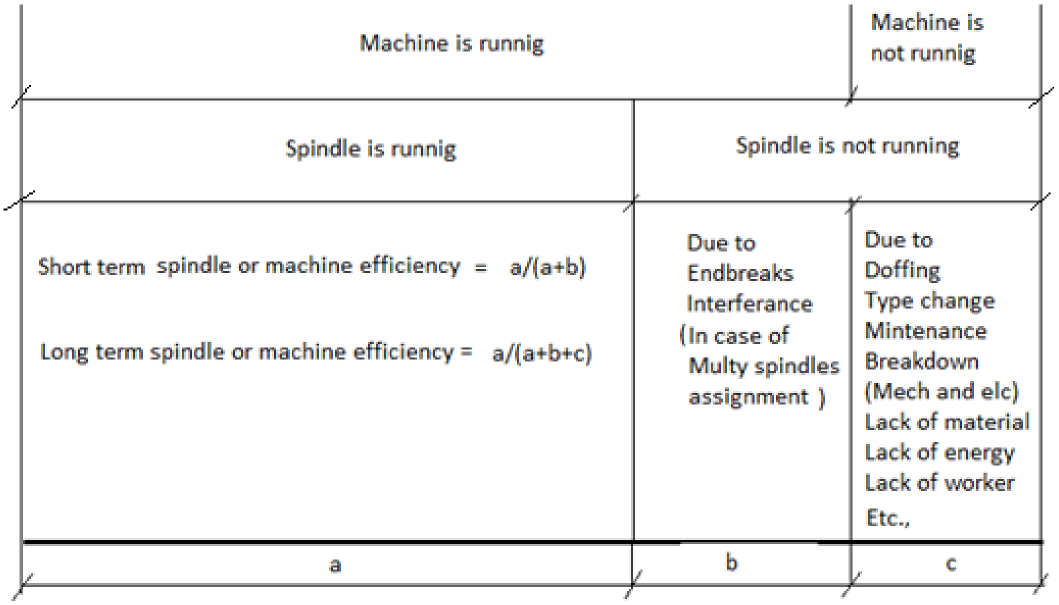

Figure 5. Illustration of short and long term spindle and machine efficiency.

Annual production calculation for 50000 spindles and for EW% efficiency is

$$\mathrm{G(kg/year)} = \frac{0{,}9 \times 15000(\mathrm{rpm}) \times \mathrm{EW}(\%)}{20\mathrm{Ne} \times \mathrm{T}''(18{,}5) \times 1000} \times 24h \times 300\ day \times 50000 spindles = 13135135{,}14\ kg \times EW(\%)$$

3. Results

The machine efficiency ultimately affects the production. In the case of stochastic machine stoppages, when an operator is assigned too many spindles like 3000-5000 spindles, the efficiency estimation becomes almost impossible. Although directly weighing the product can be considered as a solution, But this solution is neither accurate nor can answer which parameters like machine, worker and environmental conditions lead to the change production. Therefore, in this paper we elucidated the effect of the manual doffing process on the machine efficiency by using simulation technique.

We showed that the deviation from the one hundred percent doffing performance results significant loss of production and consequently loss of profit. Therefore, businesses should determine their doffing performance by means of a work study after the doffing process and then should estimate their production losses by utilizing the data presented in this study.

High lambda values are generally associated with the quality of yarn, type of yarn, machine setting, and environmental conditions. Our results indicate that high lambda values cause high production losses in the same doffing performance. Thus, businesses first should eliminate the causes affecting their doffing performance negatively. Then, by performing an economic analysis the firm can decide whether to buy several doffing machines or a ring machine integrated with doffing equipment. This economic analysis can be carried out simply by using an engineering economy formula as shown below.

$$A = P\times\frac{i\times(1+i)^{n}}{(1+i)^{n}-1}\Lambda\ \Lambda\ (4)$$

The equation utilizes the following terms and symbols:

P: value or amount of money at a time designated as the present or time. Also, P is referred to as present worth (PW), present value (PV) and net present value (NPV). Units: Dollars, Euro, etc.

A: series of consecutive, equal, end-of-period amounts of money. Also, A is called the annual worth (AW) or annuity. Units: Dollars, Euro, etc. per month, per year, etc.

n: number of interest periods. Also, n is called the economic life. Units: years, months, days, etc.
i: interest rate or rate of return per time period. Units: percent per year, percent per month, percent per day, etc.

Here: Let be
P = $130000
A =?
i= 5 %
n = 5 years

The P value of $130000 is price of 10 automatic vertical doffing machines given by a machine seller known as Ali Baba. Two automatic vertical doffing machines are for 10000 ring spindles. In this case, the total annual worth of 10 automatic vertical doffing machines for 50000 ring spindles is estimated by using Formula 4. A = $30000 approximately. This A value is indicated in Figures 6 to 8 by red lines. The decision of automation is carried out based on break-even points shown in these Figures. In this calculation, the salvage and the annually operating and maintenance of the doffing machines costs are considered negligible.

For example; assuming that the assigning number of spindles to an operator N is 3600, the yarn breaks for 1000 spindle-hour is 150, that is λ is 0,150 breaks / h, and the number of end breaks after doffing process is 190, in this case end breaks rate will be 5,27 % (190/3600) . Since 5,27 % ends breaks rate is more than the ends break rate corresponding to break even breaks point 3,44 % as indicated in Figure 8. In this case to buy separate automatic vertical doffing machines or paying the price difference between ring machines with or without integrated doffing equipment will be economical because it has lower cost.

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Table 1. The machine efficiency values obtained by considering different doffing performances and only ends breaks stoppages (N= 3600, λ= 0,050, TW= 0,000035 h, TM = 0, 0016 h)

	Case 1(100 percent performance)		Case 2(95 percent performance)		Case 3(90 percent performance)		Case 4(80 percent performance)		Case 5(75 percent performance)	
Operator cycles Z	0 % of cops are unproductive		5 % of cops are unproductive		10 % of cops are unproductive		80 20% of cops are unproductive		25 % of cops are unproductive	
	Cumulative operator and machine run times h	Cumulative machine efficiency EW %	Cumulative operator and machine run times h	Cumulative machine efficiency EW %	Cumulative operator and machine run times h	Cumulative machine efficiency EW %	Cumulative operator and machine run times h	Cumulative machine efficiency EW %	Cumulative operator and machine run times h	Cumulative machine efficiency EW %
1	0,152	99,67	0,489	96,72	0,817	93,79	1,456	88,00	1,758	85,10
2	0,329	99,58	0,734	97,51	1,127	95,10	1,886	90,18	2,252	87,72
3	0,516	99,55	0,927	97,89	1,332	95,75	2,109	91,14	2,490	88,81
4	0,702	99,54	1,114	98,16	1,518	96,21	2,304	91,84	2,682	89,57
5	0,886	99,52	1,300	98,35	1,702	96,56	2,489	92,41	2,867	90,21
6	1,066	99,52	1,478	98,49	1,887	96,85	2,670	92,89	3,050	90,77
7	1,252	99,51	1,666	98,60	2,072	97,09	2,856	93,32	3,239	91,27
8	1,437	99,51	1,854	98,68	2,258	97,28	3,035	93,69	3,427	91,72
9	1,625	99,50	2,036	98,76	2,432	97,44	3,233	94,04	3,614	92,13
10	1,810	99,50	2,215	98,82	2,618	97,58	3,417	94,33	3,788	92,47
20	3,654	99,50	4,075	99,12	4,485	98,37	5,256	96,14	5,648	94,77
30	5,510	99,49	5,932	99,23	6,334	98,69	7,138	97,02	7,508	95,93
40	7,371	99,48	7,7899	99,29	8,206	98,87	8,995	97,52	9,379	96,63
50	9,255	99,48	9,670	99,32	10,081	98,98	10,878	97,86	11,258	97,11
60	11,130	99,47	11,550	99,34	11,974	99,05	12,768	98,09	13,154	97,45
70	13,022	99,47	13,452	99,36	13,858	99,10	14,626	98,27	14,978	97,70
80	14,850	99,47	15,254	99,38	15,627	99,15	16,371	98,41	16,744	97,89
90	16,606	99,48	16,993	99,40	17,380	99,20	18,126	98,52	18,489	98,05
100	18,347	99,49	18,739	99,41	19,118	99,23	19,869	98,61	20,230	98,18
110	20,081	99,50	20,478	99,43	20,850	99,26	21,609	98,69	21,959	98,29
120	21,822	99,50	22,203	99,44	22,578	99,29	23,328	98,76	23,696	98,39
150	26,961	99,52	27,351	99,47	27,743	99,34	28,471	98,91	28,812	98,60

Table 2. The machine efficiency values obtained by considering different doffing performances and only ends breaks stoppages (N= 3600, λ = 0,100, TW = 0,000035 h, TM = 0, 0016h)

Operator cycles Z	Cumulative operator and machine run times h	Cumulative machine efficiency EW %	Cumulative operator and machine run times h	Cumulative machine efficiency EW %	Case 1(100 percent performance)	Case 2(95 percent performance	Case 3(90 percent performance)	Case 4(80 percent performance)	Case 5(75 percent performance)	Cumulative machine efficiency EW %
1	0,179	99,32	0,568	95,68	% of cops are unproductive	% of cops are unproductive	10 % of cops are unproductive	20 % of cops e unproductive	5 % of cops are unproductive	88,22
2	0,447	98,62	1,033	96,32	1,590	93,60	2,609	88,28	3,066	85,67
3	0,760	98,68	1,420	96,69	2,056	94,40	3,205	89,75	**3,719**	87,42
4	1,088	98,54	1,794	96,95	2,446	94,93	3,654	90,68	**4,192**	88,51
5	1,409	98,47	2,136	97,13	2,808	95,32	**4,040**	91,35	4,611	89,34
6	1,754	98,40	2,481	97,25	3,167	95,62	**4,404**	91,89	4,977	89,96
7	2,090	98,35	2,826	97,36	3,509	95,86	4,768	92,35	5,343	90,51
8	2,435	98,31	3,174	97,43	**3,867**	96,05	5,130	92,75	5,696	90,97
9	2,771	98,29	3,524	97,49	**4,224**	96,22	5,486	93,09	6,070	91,39
10	**3,127**	98,26	**3,878**	97,54	4,582	96,36	5,849	93,38	6,428	91,76
20	**6,698**	98,10	**7,430**	97,76	8,021	97,09	9,053	95,10	9,530	93,91
30	9,670	98,22	10,273	98,00	10,828	97,50	11,828	95,94	12,318	94,98
40	12,411	98,33	12,982	98,15	13,538	97,75	14,518	96,46	14,987	95,65
50	15,089	98,40	15,726	98,25	16,305	97,90	17,362	96,82	17,862	96,13
60	17,992	98,42	18,613	98,30	19,211	97,99	20,282	97,07	20,773	96,46
70	20,894	98,44	21,551	98,33	22,140	98,07	23,220	97,25	23,719	96,72
80	23,840	98,45	24,485	98,35	25,094	98,12	26,163	97,40	26,664	96,92
90	26,793	98,46	27,433	98,37	28,018	98,17	29,103	97,51	29,588	97,08
100	29,720	98,47	30,362	98,39	30,954	98,20	32,014	97,60	32,528	97,21
110	32,666	98,47	33,311	98,40	33,884	9823	34,958	97,68	35,470	97,32
120	35,603	98,48	36,251	98,41	36,835	98,26	37,912	97,75	38,400	97,42
150	44,412	98,50	45,038	98,45	45,623	98,32	46,695	97,91	47,180	97,63

Table 3. The machine efficiency values obtained by considering different doffing performances and only ends breaks stoppages (N= 3600, λ = 0,150, TW = 0, 000035 h, TM = 0, 0016 h)

	Case 1(100 percent performance)		Case 2(95 percent performance		Case 3(90 percent performance)		Case 4(80 percent performance)		Case 5(75 percent performance)	
Operator cycles Z	0 % of cops are unproductive		5 % of cops are unproductive		10 % of cops are unproductive		20 % of cops are unproductive		25 % of cops are unproductive	
	Cumulative operator and machine run times h	Cumulative machine efficiency EW %	Cumulative operator and machine run times h	Cumulative machine efficiency EW %	Cumulative operator and machine run times h	Cumulative machine efficiency EW %	Cumulative operator and machine run times h	Cumulative machine efficiency EW %	Cumulative operator and machine run times h	Cumulative machine efficiency EW %
1	0,214	98,79	0,670	94,28	1,086	90,04	1,864	82,28	**2,211**	78,67
2	0,634	97,62	1,494	93,84	2,254	90,28	**3,545**	83,94	**4,126**	81,10
3	1,221	96,65	2,421	93,45	**3,442**	90,40	**5,071**	85,03	5,735	82,77
4	1,958	95,79	**3,406**	93,07	**4,622**	90,40	6,320	86,08	6,942	84,13
5	2,811	95,04	**4,486**	92,68	5,731	90,60	7,310	86,96	7,912	85,17
6	**3,772**	94,38	5,535	92,52	6,649	90,95	8,148	87,67	8,727	86,00
7	**5,806**	93,78	6,432	92,64	7,444	91,30	8,871	88,24	9,448	86,67
8	6,616	93,59	7,213	92,82	8,152	91,61	9,531	88,,73	10,102	87,23
9	7,366	93,63	7,910	93,01	8,817	91,89	10,182	89,16	10,788	87,73
10	8,044	93,74	8,562	93,20	9,426	92,14	10,815	89,52	11,463	88,16
20	13,813	94,50	15,107	94,08	16,130	93,39	17,770	91,64	18,458	90,70
30	20,970	94,60	22,274	94,31	23,306	93,82	24,921	92,54	26,615	91,85
40	28,136	94,65	29,408	94,43	30,464	94,04	32,099	93,04	32,797	92,50
50	35,294	94,68	36,602	94,50	37,636	94,18	39,263	93,36	39,953	92,91
60	42,491	94,69	43,794	94,54	44,832	94,27	46,462	93,56	47,160	93,18
70	49,679	94,69	50,988	94,55	52,025	94,32	53,657	93,71	54,358	93,38
80	56,870	94,68	58,182	94,57	59,224	94,37	60,856	93,83	61,550	93,53
90	64,066	94,68	65,372	94,58	66,423	94,67	68,049	93,92	68,748	93,65
100	71,262	94,68	72,574	94,59	73,614	94,43	75,245	93,99	75,947	93,75
110	78,462	94,68	79,766	94,60	80,814	94,45	82,449	94,05	83,150	93,83
120	85,658	94,68	86,963	94,61	88,011	94,47	89,634	94,10	90,336	93,90
150	107,214	94,69	108,548	96,62	109,599	94,51	111,226	94,22	111,924	94,05

Table 4. Efficiency values obtained by using different λ, different doffing performance and by taking into account both end breaks stoppages and all type of stoppages together.

Doffing performance (percent of productive cops after replacing empty tubes) %	λ = 0,050					λ = 0,100					λ = 0,150				
	Only end break stoppages considered %	All stoppages considered %	Efficiency differences %	Loss of production annually Kg	Loss of profit annually $	Only end break stoppages considered %	All stoppages considered %	Efficiency differences %	Loss of productio annually Kg	Loss of profit annually $	Only end break stoppages considered %	All stoppage considere %	Efficiency differences %	Loss of production annually Kg	Loss of profit annually $
100	99,50	93,53	0	0	0	98,22	92,33	0	0	0	94,28	88,62	0	0	0
95	99,12	93,17	0,36	47286	10875	97,56	91,71	0,62	81437	18730	92,82	87,25	1,37	179951	41388
90	98,21	92,31	1,22	160248	36857	96,17	90,40	1,93	253508	540684	90,40	84,97	3,65	479432	110269
80	95,01	89,49	4,04	530659	122051	91,46	86,44	5,89	773659	177941	83,59	78,57	10,05	1313513	302107
75	92,87	87,29	6,24	819632	188515	88,32	83,02	9,31	1222881	281262	81,07	76,20	12,42	1631383	375218

Obtaining of the numbers shown in Table 4;
For example; for λ = 0,050
Efficiency values: 99,50 %, 99,12%, 98,21%, 95,01%, 92,87% were taken from Table 1
Efficiency values: 93,53 %, 93,17 %, 92,31 %, 89,491 %, 87,297% were obtained by multiplying the value of 0,94 = 4,11 h /(4,11h + 0,261)
For example; 93, 53% = 99, 50 % × 0, 94
Efficiency differences: 0%, 0,33 %, 1,22 %, 4,04 %, 6,24 % values were obtained by subtracting the values of % 93,17, % 92,31, % 89,49, % 87,29 from 93,53

Loss of production annualy values: They were calculated by using the formula shown bellow which was mentionned before.
G(kg/year) = 13135135,14 kg ×EW(%)
G(kg/year) = 13135135,14 kg × 0,0036 = 47286,48 kg ≈ 47286 kg
Loss of profit annualy: By assuming the loss of profit for per kg of 20 Ne cotton yarn is 0,23 $, the total annual looss of profit is found as;
47286 kg × 0,23 $/kg = 10875 $.

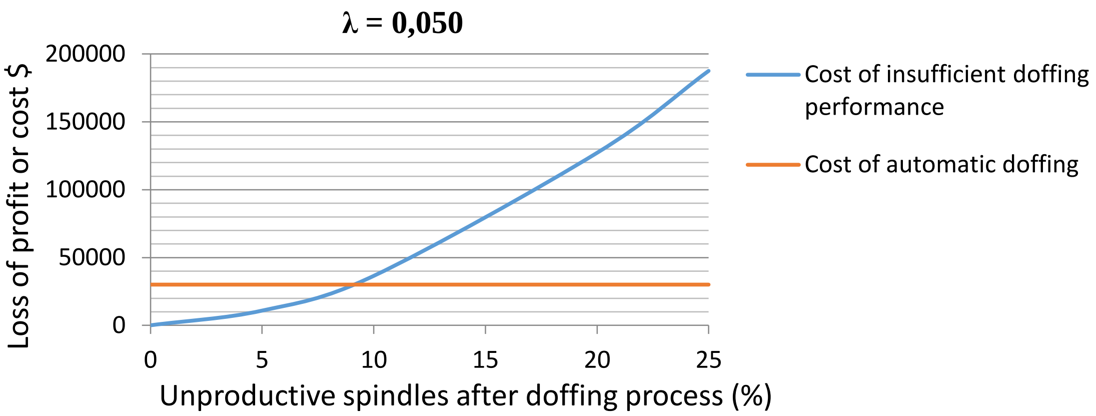

Figure 6. Breaking point for buying automatic doffing machines or for additional investment to the ring machine with doffing equipment(λ=0,050)

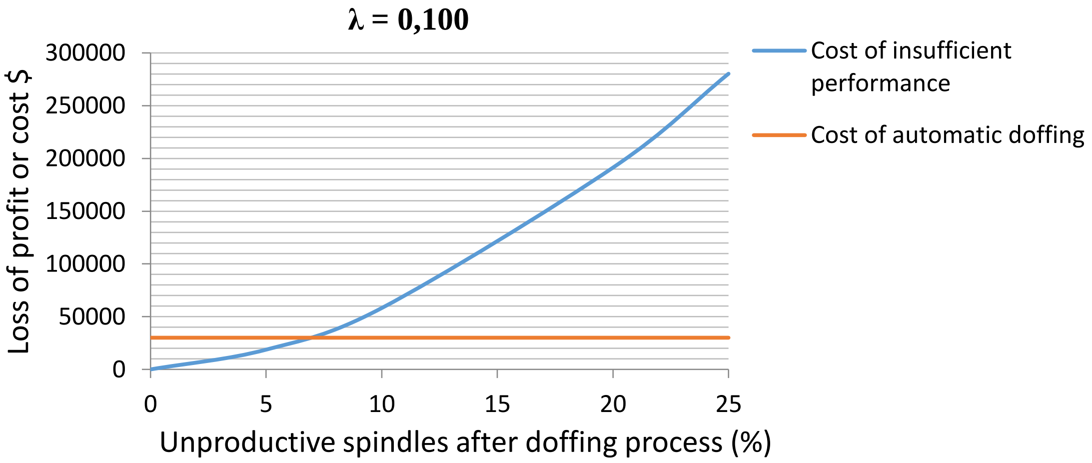

Figure 7. Breaking point for buying automatic doffing machines or for additional investment to the ring machine with doffing equipment(λ=0,100)

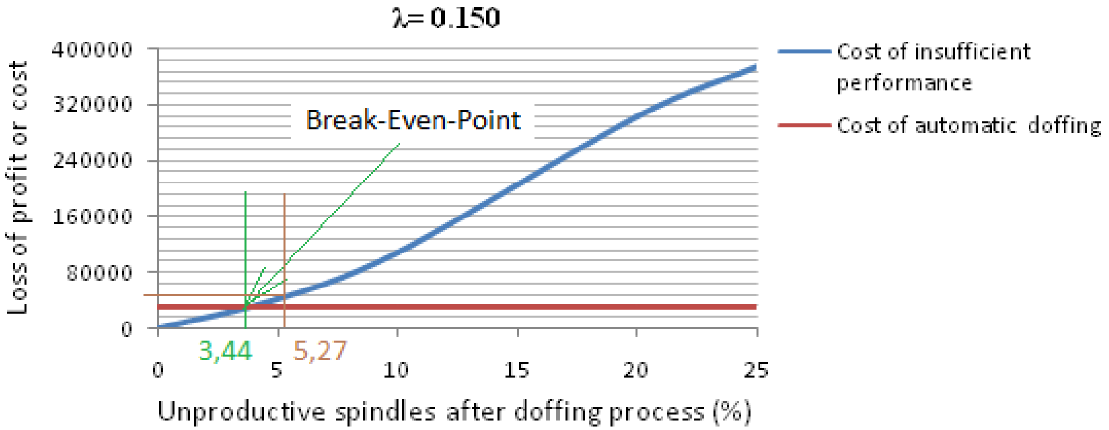

Figure 8. Breaking point for buying automatic doffing machines or for additional investment to the ring machine with doffing equipment(λ=0,150)

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