STUDY OF AVAILABILITY OF ROLLER CONVEYOR BELT SYSTEMS

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Abstract: *The final objective of this chapter is the evaluation of the operational availability of transport systems made up of four roller belt conveyers mounted in series.*

1. Introduction

Operational availability is proved during exploitation and is quantified based on operational reliability and maintainability. Availability is given by the sum of two probabilities, the probability of functioning without failure, R(t), and the probability of repair, expressed by maintainability function M(tr). Availability of a technical system can be expressed by KA availability coefficient, also called *ration of active time or intrinsic availability*.

It represents the probability for a system to function adequately in any moment, during effective functioning and repair, in specified conditions. Intrinsic availability thus excludes times in which the system halts, although it is capable of functioning, called free times, as well as preventive maintenance times, those intended for logistic, administrative and depositing actions. The indicator is defined by the equation [1]

$$KA = \frac{MTBF}{MTBF+MTTR} \qquad (1)$$

2. Reliability evaluation for roller belt conveyers

Optimization criteria used for to adopt distribution are dispersion and distance between empirical and theoretical distributions. Those distributions are adopted for which dispersion and distance has the least values. The tables presented synthesize the principal reliability indicators for the four roller belt conveyers. For each conveyer the distribution characterizing the best its functionality is adopted [12].

Table 1. *Quantitative indicators of reliability for belt conveyor TB-1. Weibull triparametric distribution Wm*

No.	Name and symbol of the indicator	Relationship	Value, unit
1	Reliability function, $R(t)$	$R(t) = e^{-\left(\frac{t-\gamma}{\eta}\right)^{\beta}} = e^{-\left(\frac{t-4,278E\text{-}9}{94,598}\right)^{3,553}}$ (2)	
2	Failure probability function, $f(t)$	$f(t) = \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1} e^{-\left(\frac{t-\gamma}{\eta}\right)^{\beta}} = \frac{3,553}{94,598}\left(\frac{t-4,278E\text{–}09}{94,598}\right)^{2,553} e^{-\left(\frac{t-4,278E\text{-}09}{94,598}\right)^{3,553}}$ (3)	
3	Failure rate function, $z(t)$	$z(t) = \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1} = \frac{3,553}{94,598}\left(\frac{t-4,278E\text{–}09}{94,598}\right)^{2,553}$ (4)	
4	Mean time between failures, $MTBF$, $E(t)$	$E(t) = \gamma + \eta\,\Gamma\left(\frac{1}{\beta}+1\right) = 4,278\cdot10^{-9}+94,598\,\Gamma\left(\frac{1}{3,553}+1\right)$ (5)	85 h
5	Median operating time, $t_{0,5}$, t_{med}	$t_{0,5} = \gamma + \eta\sqrt[\beta]{-ln\,0,5} = 4,278\cdot10^{-9}+94,598\sqrt[3,553]{-ln\,0,5}$ (6)	85 h
6	Dispersion of operating time, D	$D = \eta^2\left\{\Gamma\left(\frac{2}{\beta}+1\right)-\left[\Gamma\left(\frac{1}{\beta}+1\right)\right]^2\right\} = 94,598^2\left\{\Gamma\left(\frac{2}{3,553}+1\right)-\left[\Gamma\left(\frac{1}{3,553}+1\right)\right]^2\right\}$ (7)	707 h^2

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Table 2. *Quantitative indicators of reliability for belt conveyor TB-2. Normal normalized distribution Nv*

No.	Name and symbol of the indicator	Relationship	Value, unit
1	Reliability function, $R(t)$	$R(t)=\frac{1}{2}-\Phi\left(\frac{t-m}{\sigma}\right)=1\text{–NORMSDIST}\left(\frac{t-m}{\sigma}\right)=$ $=1\text{– NORMSDIST}\left(\frac{t-141{,}519}{56{,}505}\right)$ (8)	
2	Failure probability function, $f(t)$	$f(t)=\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{t-m}{\sigma}\right)^2}=\frac{1}{56{,}505\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{t-141{,}519}{56{,}505}\right)^2}$ (9)	
3	Failure rate function, $z(t)$	$z(t)=\frac{f(t)}{R(t)}=\frac{\frac{1}{56{,}505\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{t-141{,}519}{56{,}505}\right)^2}}{1\text{– NORMSDIST}\left(\frac{t-141{,}519}{56{,}505}\right)}$ (10)	
4	Mean time between failures, $MTBF$, $E(t)$	$MTBF=m=141{,}519$ (11)	142 h
5	Median operating time, $t_{0,5}$, t_{med}	$t_{0,5}=t_{med}=m=141{,}519$ (12)	142 h
6	Dispersion of operating time, D	$D=\sigma^2=56{,}505^2$ (13)	3193 h^2

Table 3. *Quantitative indicators of reliability for belt conveyor TB-3. Weibull triparametric distribution Wm*

No.	Name and symbol of the indicator	Relationship	Value, unit
1	Reliability function, $R(t)$	$R(t)=e^{-\left(\frac{t-\gamma}{\eta}\right)^\beta}=e^{-\left(\frac{t-1{,}121E\text{–}06}{167{,}872}\right)^{3{,}076}}$ (14)	
2	Failure probability function, $f(t)$	$f(t)=\frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1}e^{-\left(\frac{t-\gamma}{\eta}\right)^\beta}=$ $=\frac{3{,}076}{167{,}872}\left(\frac{t\text{–}1{,}121E\text{–}06}{167{,}872}\right)^{2{,}076}e^{-\left(\frac{t\text{–}1{,}121E\text{–}06}{167{,}872}\right)^{3{,}076}}$ (15)	
3	Failure rate function, $z(t)$	$z(t)=\frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1}=\frac{3{,}076}{167{,}872}\left(\frac{t-1{,}121E\text{–}06}{167{,}872}\right)^{2{,}076}$ (16)	
4	Mean time between failures, $MTBF$, $E(t)$	$E(t)=\gamma+\eta\,\Gamma\left(\frac{1}{\beta}+1\right)=1{,}121E\text{–}6+167{,}872\cdot\Gamma\left(\frac{1}{3{,}076}+1\right)$ (17)	150 h
5	Median operating time, $t_{0,5}$, t_{med}	$t_{0,5}=\gamma+\eta\sqrt[\beta]{-ln\ 0{,}5}=1{,}121E\text{–}6+167{,}872\sqrt[3{,}076]{-ln\ 0{,}5}$ (18)	141 h
6	Dispersion of operating time, D	$D=\eta^2\left\{\Gamma\left(\frac{2}{\beta}+1\right)-\left[\Gamma\left(\frac{1}{\beta}+1\right)\right]^2\right\}=$ $=167{,}872^2\left\{\Gamma\left(\frac{2}{3{,}076}+1\right)-\left[\Gamma\left(\frac{1}{3{,}076}+1\right)\right]^2\right\}$ (19)	2845 h^2

Table 4. *Quantitative indicators of reliability for belt conveyor TB-4. Weibull biparametric normalized distribution Wv*

No.	Name and symbol of the indicator	Relationship	Value, unit
1	Reliability function, $R(t)$	$R(t)=e^{-\left(\frac{t}{\eta}\right)^\beta}=e^{-\left(\frac{t}{84{,}833}\right)^{2{,}984}}$ (20)	
2	Failure probability function, $f(t)$	$f(t)=\frac{\beta}{\eta}\left(\frac{t}{\eta}\right)^{\beta-1}e^{-\left(\frac{t}{\eta}\right)^\beta}=$ $=\frac{2{,}984}{84{,}833}\left(\frac{t}{84{,}833}\right)^{1{,}984}e^{-\left(\frac{t}{84{,}833}\right)^{2{,}984}}$ (21)	
3	Failure rate function, $z(t)$	$z(t)=\frac{\beta}{\eta}\left(\frac{t}{\eta}\right)^{\beta-1}=\frac{2{,}984}{84{,}833}\left(\frac{t}{84{,}833}\right)^{1{,}984}$ (22)	
4	Mean time between failures, $MTBF$, $E(t)$	$E(t)=\eta\,\Gamma\left(\frac{1}{\beta}+1\right)=84{,}833\,\Gamma\left(\frac{1}{2{,}984}+1\right)$ (23)	76 h
5	Median operating time, $t_{0,5}$, t_{med}	$t_{0,5}=\eta\sqrt[\beta]{-ln\ 0{,}5}=84{,}833\cdot\sqrt[2{,}984]{-ln\ 0{,}5}$ (24)	75 h
6	Dispersion of operating time, D	$D=\eta^2\left\{\Gamma\left(\frac{2}{\beta}+1\right)-\left[\Gamma\left(\frac{1}{\beta}+1\right)\right]^2\right\}=$ $=84{,}833^2\left\{\Gamma\left(\frac{2}{2{,}984}+1\right)-\left[\Gamma\left(\frac{1}{2{,}984}+1\right)\right]^2\right\}$ (25)	765 h^2

Reliability function, figures 1 and 2, of the system made up of the four conveyers arranged in series is

$$R_S(t) = e^{-\left(\frac{t-4{,}278E\text{-}9}{94{,}598}\right)^{3{,}553}} \cdot \int_t^{\infty} \frac{1}{56{,}505\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{t-141{,}519}{56{,}505}\right)^2} dt \cdot e^{-\left(\frac{t-1{,}121E-06}{167{,}872}\right)^{3{,}076}} \cdot e^{-\left(\frac{t}{84{,}833}\right)^{2{,}984}} \quad (26)$$

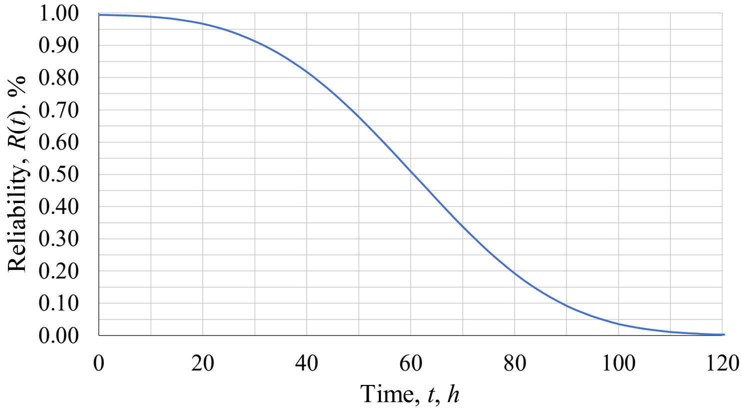

Fig. 1. *Transport system reliability function*

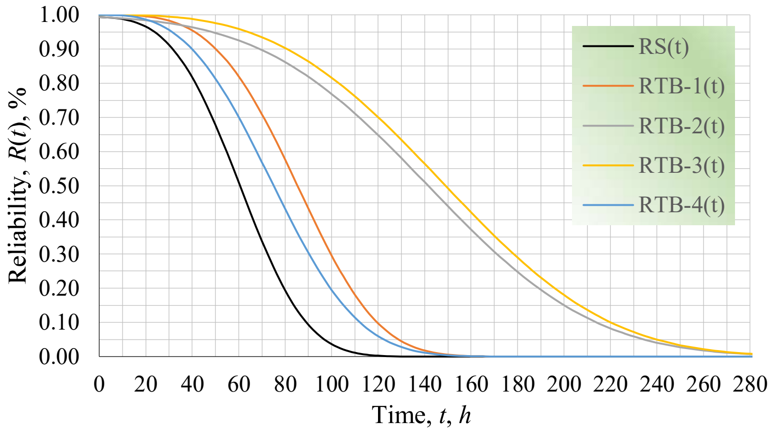

Fig. 2. *System and subsystems reliability functions*

3. Evaluation of the transport system maintainability

Optimization criteria used to adopt distributions are dispersion and distance between empirical and theoretical distributions. Those distributions are adopted for which dispersion and distance has the least values. The tables in this chapter synthesize the principal indicators of maintainability characterizing the conveyers' functionality.

Table 5. *Quantitative indicators of maintainability for belt conveyor TB-1. Lognormal normalized distribution LNv*

No.	Name and symbol of the indicator	Relationship	Value, unit
1	Maintainability function, $M(tr)$	$M(tr) = \frac{1}{2} + \Phi\left(\frac{ln\,tr - m}{\sigma}\right) = \text{NORMSDIST}\left(\frac{1}{\sigma} ln \frac{tr}{tr_{med}}\right) = \text{NORMSDIST}\left(\frac{1}{0{,}499}\ ln\ \frac{tr}{1{,}457}\right)$ (27)	
2	Repair probability function, $f(tr)$	$f(tr) = \frac{1}{tr} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{ln\,tr - m}{\sigma}\right)^2} = \frac{1}{tr} \frac{1}{0{,}499\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{ln\,tr - 0{,}376}{0{,}499}\right)^2}$ (28)	
3	Repair rate function, $z(tr)$	$z(tr) = \frac{f(tr)}{1 - M(tr)} = \frac{\frac{1}{tr}\frac{1}{0{,}499\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{ln\,tr - 0{,}376}{0{,}499}\right)^2}}{1 - \text{NORMSDIST}\left(\frac{1}{0{,}499} ln \frac{tr}{1{,}457}\right)}$ (29)	
4	Mean time to repair, $MTTR$, $E(tr)$	$MTTR = E(tr) = e^{m + \frac{\sigma^2}{2}} = e^{0{,}376 + \frac{0{,}499^2}{2}}$ (30)	1,650 h

5	Median time to repair, $tr_{0,5}$, tr_{med}	$tr_{0,5} = tr_{med} = e^{m} = e^{0,376}$ (31)	1,457 *h*
6	Maximum corrective maintenance time for P=90%, $tr_{max;0,90}$	$tr_{max;0,90} = e^{m+1,29\sigma} = e^{0,376+1,29\cdot 0,499}$ (32)	2,772 *h*
7	Maximum corrective maintenance time for 95%, $tr_{max;0,95}$	$tr_{max;0,95} = e^{m+1,64\sigma} = e^{0,376+1,64\cdot 0,499}$ (33)	3,301 *h*
8	Repair time dispersion, *D*	$D=\left(e^{\sigma^2}-1\right) e^{2m+\sigma^2}=\left(e^{0,499^2}-1\right) e^{2\cdot 0,376+0,499^2}$ (34)	0,769 h^2

Table 6. *Quantitative indicators of maintainability for belt conveyor TB-2. Lognormal normalized distribution LNv*

No.	Name and symbol of the indicator	Relationship	Value, unit
1	Maintainability function, $M(tr)$	$M(tr) = \frac{1}{2} + \Phi\left(\frac{ln\ tr - m}{\sigma}\right) = \text{NORMSDIST}\left(\frac{1}{\sigma} ln \frac{tr}{tr_{med}}\right) = \text{NORMSDIST}\left(\frac{1}{0,555}\ ln\ \frac{tr}{1,105}\right)$ (35)	
2	Repair probability function, $f(tr)$	$f(tr) = \frac{1}{tr} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{ln\ tr - m}{\sigma}\right)^2} = \frac{1}{tr} \frac{1}{0,555\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{ln\ tr - 0,100}{0,555}\right)^2}$ (36)	
3	Repair rate function, $z(tr)$	$z(tr) = \frac{f(tr)}{1-M(tr)} = \frac{\frac{1}{tr}\frac{1}{0,555\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{ln\ tr - 0,100}{0,555}\right)^2}}{1-\text{NORMSDIST}\left(\frac{1}{0,555}\ ln\ \frac{tr}{1,105}\right)}$ (37)	
4	Mean time to repair, *MTTR*, $E(tr)$	$MTTR = E(tr) = e^{m+\frac{\sigma^2}{2}} = e^{0,100+\frac{0,555^2}{2}}$ (38)	1,289 *h*
5	Median time to repair, $tr_{0,5}$, tr_{med}	$tr_{0,5} = tr_{med} = e^{m} = e^{0,100}$ (39)	1,105 *h*
6	Maximum corrective maintenance time for P=90%, $tr_{max;0,90}$	$tr_{max;0,90} = e^{m+1,29\sigma} = e^{0,100+1,29\cdot 0,555}$ (40)	2,261 *h*
7	Maximum corrective maintenance time for 95%, $tr_{max;0,95}$	$tr_{max;0,95} = e^{m+1,64\sigma} = e^{0,100+1,64\cdot 0,555}$ (41)	2,746 *h*
8	Repair time dispersion, *D*	$D=\left(e^{\sigma^2}-1\right) e^{2m+\sigma^2}=\left(e^{0,555^2}-1\right) e^{2\cdot 0,100+0,555^2}$ (42)	0,600 h^2

Table 7. *Quantitative indicators of maintainability for belt conveyor TB-3. Weibull biparametric normalized distribution Wp*

No.	Name and symbol of the indicator	Relationship	Value, unit
1	Maintainability function, $M(tr)$	$M(tr) = 1 - e^{-\left(\frac{tr}{\eta}\right)^{\beta}} = 1 - e^{-\left(\frac{tr}{1,703}\right)^{1,649}}$ (43)	
2	Repair probability function, $f(tr)$	$f(tr) = \frac{\beta}{\eta}\left(\frac{tr}{\eta}\right)^{\beta-1} e^{-\left(\frac{tr}{\eta}\right)^{\beta}} = \frac{1,649}{1,703}\left(\frac{tr}{1,703}\right)^{0,649} e^{-\left(\frac{tr}{1,703}\right)^{1,649}}$ (44)	
3	Repair rate function, $z(tr)$	$z(tr) = \frac{\beta}{\eta}\left(\frac{tr}{\eta}\right)^{\beta-1} = \frac{1,649}{1,703}\left(\frac{tr}{1,703}\right)^{0,649}$ (45)	
4	Mean time to repair, *MTTR*, $E(tr)$	$MTTR = \eta\ \Gamma\left(\frac{1}{\beta}+1\right) = 1,703\ \Gamma\left(\frac{1}{1,649}+1\right)$ (46)	1,523 *h*
5	Median time to repair, $tr_{0,5}$, tr_{med}	$tr_{0,5} = \eta\ \sqrt[\beta]{-ln\ 0,5} = 1,703\cdot \sqrt[1,649]{-ln\ 0,5}$ (47)	1,364 *h*
6	Maximum corrective maintenance time for P=90%, $tr_{max;0,90}$	$tr_{max;0,90} = \eta\ \sqrt[\beta]{-ln\ 0,1} = 1,703\cdot \sqrt[1,649]{-ln\ 0,1}$ (48)	2,824 *h*
7	Maximum corrective maintenance time for 95%, $tr_{max;0,95}$	$tr_{max;0,95} = \eta\ \sqrt[\beta]{-ln\ 0,05} = 1,703\cdot \sqrt[1,649]{-ln\ 0,05}$ (49)	3,313 *h*
8	Repair time dispersion, *D*	$D = \eta^2\left\{\Gamma\left(\frac{2}{\beta}+1\right) - \left[\Gamma\left(\frac{1}{\beta}+1\right)\right]^2\right\} = 1,703^2\left\{\Gamma\left(\frac{2}{1,649}+1\right) - \left[\Gamma\left(\frac{1}{1,649}+1\right)\right]^2\right\}$ (50)	0,899 h^2

Table 8. *Quantitative indicators of maintainability for belt conveyor TB-4. Weibull biparametric normalized distribution Wp*

No.	Name and symbol of the indicator	Relationship	Value, unit
1	Maintainability function, $M(tr)$	$M(tr) = 1 - e^{-\left(\frac{tr}{\eta}\right)^{\beta}} = 1 - e^{-\left(\frac{tr}{1,848}\right)^{1,595}}$ (51)	
2	Repair probability function, $f(tr)$	$f(tr) = \frac{\beta}{\eta}\left(\frac{tr}{\eta}\right)^{\beta-1} e^{-\left(\frac{tr}{\eta}\right)^{\beta}} = \frac{1,595}{1,848}\left(\frac{tr}{1,848}\right)^{0,595} e^{-\left(\frac{tr}{1,848}\right)^{1,595}}$ (52)	
3	Repair rate function, $z(tr)$	$z(tr) = \frac{\beta}{\eta}\left(\frac{tr}{\eta}\right)^{\beta-1} = \frac{1,595}{1,848}\left(\frac{tr}{1,848}\right)^{0,595}$ (53)	
4	Mean time to repair, $MTTR$, $E(tr)$	$MTTR = \eta\,\Gamma\left(\frac{1}{\beta}+1\right) = 1,848\,\Gamma\left(\frac{1}{1,595}+1\right)$ (54)	1,657 *h*
5	Median time to repair, $tr_{0,5}$, tr_{med}	$tr_{0,5} = \eta\sqrt[\beta]{-ln\ 0,5} = 1,848 \cdot \sqrt[1,595]{-ln\ 0,5}$ (55)	1,469 *h*
6	Maximum corrective maintenance time for P=90%, $tr_{max;0,90}$	$tr_{max;0,90} = \eta\sqrt[\beta]{-ln\ 0,1} = 1,848 \cdot \sqrt[1,595]{-ln\ 0,1}$ (56)	3,117 *h*
7	Maximum corrective maintenance time for 95%, $tr_{max;0,95}$	$tr_{max;0,95} = \eta\sqrt[\beta]{-ln\ 0,05} = 1,848 \cdot \sqrt[1,595]{-ln\ 0,05}$ (57)	3,677 *h*
8	Repair time dispersion, D	$D = \eta^2\left\{\Gamma\left(\frac{2}{\beta}+1\right) - \left[\Gamma\left(\frac{1}{\beta}+1\right)\right]^2\right\} = 1,848^2\left\{\Gamma\left(\frac{2}{1,595}+1\right) - \left[\Gamma\left(\frac{1}{1,595}+1\right)\right]^2\right\}$ (58)	1,131 h^2

4. Evaluation of the availability of transport system

For a component subsystem of the system, the indicator is expressed by the equation

$$A_i(t) = KA_i = \frac{MTBF_i}{MTBF_i + MTTR_i} \quad (59)$$

where i means TB-1, TB-2, TB-3 or TB-4.

In this equation, MTBFi represents the average good functioning times (times between failures), and MTTRi the average time related to repairs.

Unavailability, Ui(t), defined by the equation

$$U_i(t) = 1 - A_i(t), \quad (60)$$

expresses the time ratio where the system cannot be used.

For the system series made up of the four conveyers, the availability is

$$A_S(t) = \prod_{i=1}^{4} A_i(t) = A_{TB\text{-}1}(t) \cdot A_{TB\text{-}2}(t) \cdot A_{TB\text{-}3}(t) \cdot A_{TB\text{-}4}(t) \quad (61)$$

Table 9. *Availability evaluation of roller belt conveyors and transport system*

No.	Conveyor	Number of failures, *n*	$MTBF_i$		$MTTR_i$		$A_i(t)$, $\frac{MTBF_i}{MTBF_i+MTTR_i}$	$U_i(t)$, $U_i(t)=1-A_i(t)$, *ore/an*; *zile/an*
			Value, *h*	Distribution/ relationship	Value, *h*	Distribution/ relationship		
1	Conveyor TB-1	49	85,183	*Wm*/(4.28)	1,650	*LNv*/(4.123)	0,980998	166; 6,93
2	Conveyor TB-2	31	141,519	*Nv*/(4.34)	1,289	*LNv*/(4.163)	0,990974	79; 3,29
3	Conveyor TB-3	28	150,075	*Wm*/(4.76)	1,523	*Wp*/(4.218)	0,989954	88; 3,67
4	Conveyor TB-4	56	75,736	*Wv*/(4.94)	1,657	*Wp*/(4.257)	0,978590	188; 7,81
5	Transport system: AS(t) = 0,941773; US(t) = 510 *hours/year*; US(t) = 21 *days/year*							

In another variant, the system availability can be calculated knowing the system's reliability function, RS(t). In this case, availability AS(t) of the system results from the equation

$$A_S(t) = \frac{MTBF_S}{MTBF_S + MTTR_S} \quad (62)$$

In this equation, $MTBF_S$ represents the average good functioning time for the system, and $MTTR_S$ the average of the repair of the system.

$MTBF_S$ indicator results from the equation

$$MTBF_S = \int_0^{\infty} R_S(t)\,dt =$$

$$= \int_0^{\infty}\left[e^{-\left(\frac{t-4,278E\text{-}9}{94,598}\right)^{3,553}} \cdot \int_t^{\infty}\frac{1}{56,505\sqrt{2\pi}}\,e^{-\frac{1}{2}\left(\frac{t-141,519}{56,505}\right)^2}dt \cdot e^{-\left(\frac{t-1,121E-06}{167,872}\right)^{3,076}} \cdot e^{-\left(\frac{t}{84,833}\right)^{2,984}}\right]dt \quad (63)$$

Solving with Mathcad software the integral leads to the parameter value for the system, $MTBF_S$ = 60,436 *hours*.

In order to determine $MTTR_S$ parameter, the unit made up of the four conveyers as a single product characterized by the 164 failures is considered.

The statistic series with 164 terms is made up of repair times tr_i, in *hours*: 0,500; 0,583; 0,667; 0,667; 0,667; 0,750; 0,7500; 0,833; 0,833; 0,917; 1,083; 1,167; 1,250; 1,250; 1,250; 1,417; 1,583; 1,583; 1,750; 2,000; 2,083; 2,250; 3,167; 4,167; 4,250; 4,917; 0,417; 0,500; 0,500, 0,500; 0,500; 0,500; 0,583; 0,667; 0,667; 0,667; 0,750; 0,750; 0,750; 0,833; 0,833; 0,833; 0,917; 0,917; 0,917; 0,917; 1,000; 1,000; 1,083; 1,083; 1,083; 1,083; 1,250; 1,250; 1,250; 1,250; 1,250; 1,250; 1,250; 1,250; 1,333; 1,333; 1,417; 1,417; 1,500; 1,667; 1,750; 1,833; 1,833; 2,000; 2,083; 2,250; 2,333; 2,500; 3,083; 3,583; 3,667; 4,083; 4,250; 4,500; 6,667; 12,000.

Statistic processing of the series shows that repair times of the entire system follow a lognormal distribution law, defined by the following parameters:

- average, $m(lg\ tr)$ = AVERAGE $ln(tri)$ (1:164) = 0,254417 h;
- median, $t_{med}\ (lg\ tr) = e^{m(lg\ tr)}$=1,289710 h;
- shape parameter, $\sigma(lg\ tr)$ = STDEV $ln\ (tri)$ (1:164) = 0,615947
- distribution function, $M(tri)$ = NORMSDIST $ln\left(\frac{tr_i}{tr_{med}}\right)\frac{1}{\sigma}$.

With these values, the parameter $MTTR_S$ is

$$MTTR_S = E(tr)_S = e^{m + \frac{\sigma^2}{2}} = e^{0,254417 + \frac{0,615947^2}{2}} = 1,559\ h.$$

This value of the repair time average for the system is not realistic, in reality it being much higher. For a 95% certainty level, $MTTR_S = tr_{max;0,95} = e^{m + 1,64\sigma} = e^{0,254417 + 1,64 \cdot 0,615947} = 3,541\ h$.

With the average value of functioning and repair times $A_S(t)$ availability of the system is $A_S(t) = \frac{MTBF_S}{MTBF_S + MTTR_S} = \frac{60,436}{60,436+3,541} = 0,944652 =$ 94,4652%.

Reported to one *year*, $U_S(t)$ = 485 *hours*, respectively $U_S(t)$ = 20 *days* of unavailability result.

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