

# Effect of Machine Speed on Type of Defect During Knitting Process of Ladies Tights

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#### INTRODUCTION

Quality has been identified as one of the competitive strategies for improving business performance in a global market. The best-proposed tool for better-quality products is Statistical Process Control. The paper investigates the concepts of the quality control tool - scatter diagram, correlation coefficient, and regression analysis in the production of lady's tights.

## **EXPERIMENTAL PART**

First findings, by collected production information's with usage of check lists and Pareto charts, for both machines are that the highest percentage of defects occurs from breaking thread 2. Usually the machines work with speed of n = 500 - 650 rpm, set up by the appropriate knitting program. At the table, separated on two parts are presented the data for average speed of the machine (values x) and the defects- tearing the thread performed during that speed (values y) while knitting the pipes. The purpose of this is to see if there is a correlation between the knitting speed and defects. If so, to find the speed at which the defects are the least.

## **RESULTS AND DISCUSSION**

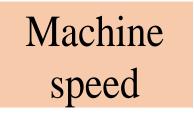
For the first set of machine speed, the calculated values of the coefficient of correlation indicate a high inverse-proportional linear correlation between the average knitting speed and the tearing of the thread, i.e. the defects that occur. So, there is a linear correlation with a confidence level of 99,9 %. Next, aiming to explain the quantitative correlation between the variables, regression analysis is performed, which is designed in Figure 1. The result for the regression coefficient indicates that 92 % of the points (values for tearing of the thread) are near the regression line. The same calculation as above is performed for the second part of the obtained results, for machine speed 600 - 650 rev/min.

 Table 1: Machine speed and defects and calculation

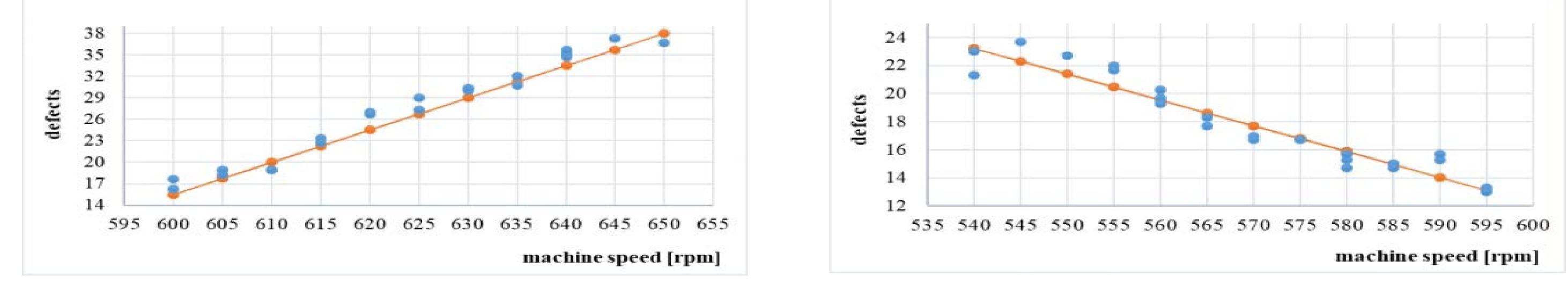
for correlation coefficient

No.12345678910111213141516171819202122232425sum26272829	x540550550550560565570575580585590595545540555560570575580570575580570575580570575580585590580585590580 <tr< th=""><th>y2322,72220,318,31716,715,715,313,323,721,321,719,716,716,715,314,715,71319,315,714,714,714,714,714,7</th><th>1242012485122101136810339,596909602,59106877590277913,512916,51150212043,51103210000,595199602,588748599,5926377351080891068526</th><th>x²2916003025003080253136003192253249003306253364003422253481003540252970252916003080253136003192253249003306253136003192253249003192253249003192253136003192253249003306253136400342025348100354025348100354025348100354025348100354025348100354025348100354025348100354025313600336400336400336400</th><th>y²529515,29484412,09334,89289278,89246,49225234,09176,89561,69453,69470,89388,09313,29278,89278,89278,89278,89278,89278,89278,89278,89278,89234,09216,09246,49169372,49246,49</th></tr<>	y2322,72220,318,31716,715,715,313,323,721,321,719,716,716,715,314,715,71319,315,714,714,714,714,714,7	1242012485122101136810339,596909602,59106877590277913,512916,51150212043,51103210000,595199602,588748599,5926377351080891068526	x²2916003025003080253136003192253249003306253364003422253481003540252970252916003080253136003192253249003306253136003192253249003192253249003192253136003192253249003306253136400342025348100354025348100354025348100354025348100354025348100354025348100354025348100354025313600336400336400336400	y²529515,29484412,09334,89289278,89246,49225234,09176,89561,69453,69470,89388,09313,29278,89278,89278,89278,89278,89278,89278,89278,89278,89234,09216,09246,49169372,49246,49
23456789101112131415161718192021232425sum262728	550555560565570575580585590595545540555560570575580585590585590595580580585590585580580580580580580580580580580580580580580580580580	$\begin{array}{r} 22,7\\22\\20,3\\18,3\\17\\16,7\\16,7\\15,7\\15,7\\15,3\\13,3\\23,7\\21,3\\23,7\\21,3\\23,7\\21,3\\21,7\\19,7\\17,7\\16,7\\16,7\\16,7\\15,3\\14,7\\15,7\\15,7\\13\\19,3\\15,7\\14,7\end{array}$	12485122101136810339,596909602,59106877590277913,512916,51150212043,51103210000,595199602,588748599,592637735108089106	3025003080253136003192253249003306253364003422253481003540252970252916003080253136003192253249003306253136003422253481003192253249003306253136003422253481003540253481003540253136003136400354025348100354025313600313600313600313600313600313600313600313600313600	$\begin{array}{r} 515,29\\ 484\\ 412,09\\ 334,89\\ 289\\ 289\\ 278,89\\ 246,49\\ 225\\ 234,09\\ 176,89\\ 561,69\\ 453,69\\ 453,69\\ 470,89\\ 388,09\\ 313,29\\ 278,89\\ 278,89\\ 278,89\\ 278,89\\ 278,89\\ 278,89\\ 278,89\\ 234,09\\ 169\\ 372,49\\ 246,49\\ 169\\ 372,49\\ 246,49\end{array}$
3456789101112131415161718192021232425sum262728	555560565570570575580585590595545540555560570575580585590595590595560580585590580580580580580580580580580580	$\begin{array}{c} 22\\ 20,3\\ 18,3\\ 17\\ 16,7\\ 16,7\\ 15,7\\ 15,3\\ 13,3\\ 23,7\\ 21,3\\ 23,7\\ 21,3\\ 23,7\\ 21,3\\ 21,7\\ 19,7\\ 17,7\\ 16,7\\ 16,7\\ 16,7\\ 15,3\\ 14,7\\ 15,7\\ 13\\ 19,3\\ 15,7\\ 14,7\\ \end{array}$	122101136810339,596909602,59106877590277913,512916,51150212043,51103210000,595199602,588748599,592637735108089106	308025 313600 319225 324900 330625 336400 342225 348100 354025 297025 297025 291600 308025 313600 319225 324900 330625 324900 330625 336400 342225 348100 354025 313600 3354025	$\begin{array}{r} 484 \\ 412,09 \\ 334,89 \\ 289 \\ 278,89 \\ 246,49 \\ 225 \\ 234,09 \\ 176,89 \\ 561,69 \\ 453,69 \\ 453,69 \\ 470,89 \\ 388,09 \\ 313,29 \\ 278,89 \\ 278,89 \\ 278,89 \\ 278,89 \\ 278,89 \\ 278,89 \\ 234,09 \\ 216,09 \\ 246,49 \\ 169 \\ 372,49 \\ 246,49 \\ \end{array}$
456789101112131415161718192021232425sum262728	560565570570575580585590595545540555560565570575580585590595560595560585590595580580580580580580580580580	$\begin{array}{c} 22\\ 20,3\\ 18,3\\ 17\\ 16,7\\ 16,7\\ 15,7\\ 15,3\\ 13,3\\ 23,7\\ 21,3\\ 23,7\\ 21,3\\ 23,7\\ 21,3\\ 21,7\\ 19,7\\ 17,7\\ 16,7\\ 16,7\\ 16,7\\ 15,3\\ 14,7\\ 15,7\\ 13\\ 19,3\\ 15,7\\ 14,7\\ \end{array}$	1136810339,596909602,59106877590277913,512916,51150212043,51103210000,595199602,588748599,592637735108089106	3136003192253249003306253364003422253481003540252970252916003080253136003192253249003306253364003481003481003481003540253136003136003136003136003136400	$\begin{array}{r} 412,09\\ 334,89\\ 289\\ 289\\ 278,89\\ 246,49\\ 225\\ 234,09\\ 176,89\\ 561,69\\ 453,69\\ 453,69\\ 470,89\\ 388,09\\ 313,29\\ 278,89\\ 278,89\\ 278,89\\ 278,89\\ 278,89\\ 278,89\\ 234,09\\ 216,09\\ 246,49\\ 169\\ 372,49\\ 246,49\end{array}$
5678910111213141516171819202122232425sum262728	560565570570575580585590595545540555560565570575580585590595560595560585590595580580580580580580580580580	$\begin{array}{c} 20,3\\ 18,3\\ 17\\ 16,7\\ 16,7\\ 15,7\\ 15,3\\ 13,3\\ 23,7\\ 21,3\\ 23,7\\ 21,3\\ 21,7\\ 19,7\\ 17,7\\ 19,7\\ 17,7\\ 16,7\\ 16,7\\ 16,7\\ 15,3\\ 14,7\\ 15,7\\ 13\\ 19,3\\ 15,7\\ 14,7\\ 14,7\\ \end{array}$	1136810339,596909602,59106877590277913,512916,51150212043,51103210000,595199602,588748599,592637735108089106	3136003192253249003306253364003422253481003540252970252916003080253136003192253249003306253364003481003481003481003540253136003136003136003136003136400	$\begin{array}{r} 412,09\\ 334,89\\ 289\\ 289\\ 278,89\\ 246,49\\ 225\\ 234,09\\ 176,89\\ 561,69\\ 453,69\\ 453,69\\ 470,89\\ 388,09\\ 313,29\\ 278,89\\ 278,89\\ 278,89\\ 278,89\\ 278,89\\ 278,89\\ 234,09\\ 216,09\\ 246,49\\ 169\\ 372,49\\ 246,49\end{array}$
5678910111213141516171819202122232425sum262728	565570575580585590595545540555560570575580585590595560595560580595560580580580580580580580580580580580580580	$     \begin{array}{r}       18,3 \\       17 \\       16,7 \\       15,7 \\       15,7 \\       15,3 \\       13,3 \\       23,7 \\       21,3 \\       21,3 \\       21,3 \\       21,7 \\       19,7 \\       17,7 \\       16,7 \\       16,7 \\       16,7 \\       16,7 \\       15,3 \\       14,7 \\       15,7 \\       13 \\       19,3 \\       15,7 \\       14,7$	10339,5 9690 9602,5 9106 8775 9027 7913,5 12916,5 12916,5 11502 12043,5 11032 12043,5 11032 10000,5 9519 9519 9602,5 8874 8599,5 9263 7735 10808 9106	319225324900330625336400342225348100354025297025291600308025313600319225324900330625336400342225348100354025313600313600313600313600313600336400336400336400336400336400336400	$\begin{array}{r} 334,89\\ 289\\ 289\\ 278,89\\ 246,49\\ 225\\ 234,09\\ 176,89\\ 561,69\\ 453,69\\ 470,89\\ 388,09\\ 313,29\\ 278,89\\ 278,89\\ 278,89\\ 278,89\\ 278,89\\ 234,09\\ 216,09\\ 216,09\\ 169\\ 372,49\\ 246,49\\ 169\\ 372,49\\ 246,49\end{array}$
6 $7$ $8$ $9$ $10$ $11$ $12$ $13$ $14$ $15$ $16$ $17$ $18$ $19$ $20$ $21$ $22$ $23$ $24$ $25$ $sum$ $26$ $27$ $28$	570575580585590595545540555560565570575580585590595560580580580580580580580580580580580580580580580580580	$     \begin{array}{r}       17 \\       16,7 \\       15,7 \\       15,7 \\       15,3 \\       13,3 \\       23,7 \\       21,3 \\       21,3 \\       21,7 \\       19,7 \\       17,7 \\       16,7 \\       16,7 \\       16,7 \\       16,7 \\       15,3 \\       14,7 \\       15,7 \\       13 \\       19,3 \\       15,7 \\       14,7$	9690 9602,5 9106 8775 9027 7913,5 12916,5 12916,5 11502 12043,5 11032 10000,5 9519 9602,5 8874 8874 8599,5 9263 7735 10808 9106	324900 330625 336400 342225 348100 354025 297025 297025 291600 308025 313600 319225 324900 330625 324900 330625 336400 342225 348100 354025 313600 336400	$\begin{array}{r} 289 \\ 278,89 \\ 246,49 \\ 225 \\ 234,09 \\ 176,89 \\ 561,69 \\ 453,69 \\ 470,89 \\ 388,09 \\ 313,29 \\ 278,89 \\ 278,89 \\ 278,89 \\ 278,89 \\ 234,09 \\ 216,09 \\ 246,49 \\ 169 \\ 372,49 \\ 246,49 \\ \end{array}$
$     \begin{array}{r}       7 \\       8 \\       9 \\       10 \\       11 \\       12 \\       13 \\       14 \\       15 \\       16 \\       17 \\       18 \\       19 \\       20 \\       21 \\       18 \\       19 \\       20 \\       21 \\       22 \\       23 \\       24 \\       25 \\       sum \\       24 \\       25 \\       sum \\       26 \\       27 \\       28 \\       \end{array} $	$\begin{array}{c} 575 \\ 580 \\ 585 \\ 590 \\ 595 \\ 545 \\ 545 \\ 540 \\ 555 \\ 540 \\ 555 \\ 560 \\ 565 \\ 570 \\ 575 \\ 580 \\ 585 \\ 590 \\ 595 \\ 590 \\ 595 \\ 580 \\$	$     \begin{array}{r} 16,7 \\     15,7 \\     15,3 \\     15,3 \\     13,3 \\     23,7 \\     21,3 \\     21,7 \\     19,7 \\     19,7 \\     17,7 \\     16,7 \\     16,7 \\     16,7 \\     16,7 \\     15,3 \\     14,7 \\     15,7 \\     13 \\     19,3 \\     15,7 \\     14,7 \\     1$	9602,5 9106 8775 9027 7913,5 12916,5 11502 12043,5 11032 10000,5 9519 9602,5 8874 8599,5 9263 7735 10808 9106	330625 336400 342225 348100 354025 297025 297025 291600 308025 313600 319225 324900 330625 324900 330625 336400 342225 348100 354025 313600 336400	$\begin{array}{r} 278,89\\ 246,49\\ 225\\ 234,09\\ 176,89\\ 561,69\\ 453,69\\ 470,89\\ 388,09\\ 313,29\\ 278,89\\ 278,89\\ 278,89\\ 278,89\\ 278,89\\ 234,09\\ 216,09\\ 246,49\\ 169\\ 372,49\\ 246,49\end{array}$
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910111213141516171819202122232425sum262728	585         590         595         545         540         555         560         565         570         575         580         585         590         595         580         595         560         580         590         595         560         580         580         580         580         580         580         580         580         580         580         580	$ \begin{array}{r} 15 \\ 15,3 \\ 13,3 \\ 23,7 \\ 21,3 \\ 21,7 \\ 19,7 \\ 17,7 \\ 16,7 \\ 16,7 \\ 16,7 \\ 16,7 \\ 15,3 \\ 14,7 \\ 15,7 \\ 13 \\ 19,3 \\ 15,7 \\ 14,7 \\ 14,7 \\ \end{array} $	8775 9027 7913,5 12916,5 11502 12043,5 11032 10000,5 9519 9602,5 8874 8599,5 9263 7735 10808 9106	342225 348100 354025 297025 297025 291600 308025 313600 319225 324900 330625 324900 330625 336400 342225 348100 354025 313600 336400	$\begin{array}{r} 225\\ 234,09\\ 176,89\\ 561,69\\ 453,69\\ 470,89\\ 388,09\\ 313,29\\ 278,89\\ 278,89\\ 278,89\\ 278,89\\ 234,09\\ 234,09\\ 216,09\\ 246,49\\ 169\\ 372,49\\ 246,49\end{array}$
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111213141516171819202122232425sum262728	595         545         540         555         560         565         570         575         580         585         590         595         560         585         590         595         560         580         580         595         560         580         580         580         580         580         580         580         580	$ \begin{array}{c} 13,3\\ 23,7\\ 21,3\\ 21,7\\ 19,7\\ 19,7\\ 17,7\\ 16,7\\ 16,7\\ 16,7\\ 15,3\\ 14,7\\ 15,7\\ 13\\ 19,3\\ 15,7\\ 14,7\\ 14,7\\ 14,7\\ \end{array} $	7913,5 12916,5 11502 12043,5 11032 10000,5 9519 9602,5 8874 8599,5 9263 7735 10808 9106	354025 297025 291600 308025 313600 319225 324900 330625 336400 342225 348100 354025 313600 336400	$     \begin{array}{r}       176,89 \\       561,69 \\       453,69 \\       470,89 \\       388,09 \\       313,29 \\       278,89 \\       278,89 \\       278,89 \\       234,09 \\       216,09 \\       246,49 \\       169 \\       372,49 \\       246,49 \\     \end{array} $
1213141516171819202122232425sum262728	545         540         555         560         565         570         575         580         585         590         595         560         580         590         595         560         580         580         580         580         580         580         580         580         580         580         580	$\begin{array}{c} 23,7\\ 21,3\\ 21,7\\ 19,7\\ 19,7\\ 17,7\\ 16,7\\ 16,7\\ 16,7\\ 15,3\\ 14,7\\ 15,7\\ 13\\ 19,3\\ 15,7\\ 14,7\\ 14,7\\ \end{array}$	12916,5 11502 12043,5 11032 10000,5 9519 9602,5 8874 8599,5 9263 7735 10808 9106	297025 291600 308025 313600 319225 324900 330625 336400 342225 348100 354025 313600 336400	561,69 $453,69$ $470,89$ $388,09$ $313,29$ $278,89$ $278,89$ $234,09$ $216,09$ $246,49$ $169$ $372,49$ $246,49$
13141516171819202122232425sum262728	540         555         560         565         570         575         580         585         590         595         560         580         590         595         560         580         580         580         580         580         580	$\begin{array}{c} 21,3\\ 21,7\\ 19,7\\ 19,7\\ 17,7\\ 16,7\\ 16,7\\ 16,7\\ 15,3\\ 14,7\\ 15,7\\ 13\\ 19,3\\ 15,7\\ 14,7\\ 14,7\\ \end{array}$	11502         12043,5         11032         10000,5         9519         9602,5         8874         8599,5         9263         7735         10808         9106	291600 308025 313600 319225 324900 330625 336400 342225 348100 354025 313600 336400	$\begin{array}{r} 453,69\\ 470,89\\ 388,09\\ 313,29\\ 278,89\\ 278,89\\ 278,89\\ 234,09\\ 216,09\\ 246,49\\ 169\\ 372,49\\ 246,49\\ 246,49\end{array}$
141516171819202122232425sum262728	555         560         565         570         570         575         580         585         590         595         560         580         595         560         580         580         595         560         580         580	$\begin{array}{c} 21,7\\ 19,7\\ 17,7\\ 16,7\\ 16,7\\ 16,7\\ 15,3\\ 14,7\\ 15,7\\ 13\\ 19,3\\ 15,7\\ 14,7\\ 14,7\\ \end{array}$	12043,5 11032 10000,5 9519 9602,5 8874 8599,5 9263 7735 10808 9106	308025313600319225324900330625336400342225348100354025313600336400	$\begin{array}{r} 470,89\\ 388,09\\ 313,29\\ 278,89\\ 278,89\\ 234,09\\ 234,09\\ 216,09\\ 246,49\\ 169\\ 372,49\\ 246,49\\ 246,49\end{array}$
1516171819202122232425sum262728	560 565 570 575 580 585 590 595 590 595 590 595 560 580 580 580	$     \begin{array}{r}       19,7\\       17,7\\       16,7\\       16,7\\       15,3\\       14,7\\       15,7\\       13\\       19,3\\       15,7\\       14,7\\       14,7   \end{array} $	1103210000,595199602,588748599,592637735108089106	313600319225324900330625336400342225348100354025313600336400	388,09 313,29 278,89 278,89 234,09 216,09 246,49 169 372,49 246,49
16171819202122232425sum262728	565         570         575         580         585         590         595         560         580         580         595         560         580         580	$ \begin{array}{r} 17,7\\ 16,7\\ 16,7\\ 15,3\\ 14,7\\ 15,7\\ 13\\ 19,3\\ 15,7\\ 14,7\\ 14,7\\ \end{array} $	10000,5 9519 9602,5 8874 8599,5 9263 7735 10808 9106	319225324900330625336400342225348100354025313600336400	313,29 278,89 278,89 234,09 216,09 246,49 169 372,49 246,49
171819202122232425sum262728	570 575 580 585 590 595 595 560 580 580	$     \begin{array}{r}       16,7 \\       16,7 \\       15,3 \\       14,7 \\       15,7 \\       13 \\       19,3 \\       15,7 \\       14,7 \\       14,7 \\     \end{array} $	9519 9602,5 8874 8599,5 9263 7735 10808 9106	324900 330625 336400 342225 348100 354025 313600 336400	278,89 278,89 234,09 216,09 246,49 169 372,49 246,49
1819202122232425sum262728	575 580 585 590 595 560 580 580	$     \begin{array}{r}       16,7 \\       15,3 \\       14,7 \\       15,7 \\       13 \\       19,3 \\       15,7 \\       14,7 \\       14,7 \\     \end{array} $	9602,5 8874 8599,5 9263 7735 10808 9106	330625336400342225348100354025313600336400	278,89 234,09 216,09 246,49 169 372,49 246,49
19202122232425sum262728	580 585 590 595 560 580 580	15,3 14,7 15,7 13 19,3 15,7 14,7	8874 8599,5 9263 7735 10808 9106	336400342225348100354025313600336400	234,09 216,09 246,49 169 372,49 246,49
202122232425sum262728	585 590 595 560 580 580	14,7 15,7 13 19,3 15,7 14,7	8599,5 9263 7735 10808 9106	342225 348100 354025 313600 336400	216,09 246,49 169 372,49 246,49
2122232425sum262728	590 595 560 580 580	15,7 13 19,3 15,7 14,7	9263 7735 10808 9106	348100 354025 313600 336400	246,49 169 372,49 246,49
22         23         24         25         sum         26         27         28	595 560 580 580	13 19,3 15,7 14,7	7735 10808 9106	354025 313600 336400	169 372,49 246,49
23 24 25 sum 26 27 28	560 580 580	19,3 15,7 14,7	10808 9106	313600 336400	372,49 246,49
24 25 sum 26 27 28	580 580	15,7 14,7	9106	336400	246,49
25 sum 26 27 28	580	14,7			,
sum           26           27           28		14,7	8526	226100	,
sum           26           27           28		,		I JJU4UU	216,09
26 27 28			252464	8123375	8171,8
27 28		/			
27 28	600	16,3	9780	360000	265,69
28	605	18,3	11071,5	366025	334,89
	610	19	11590	372100	361
	615	23,3	14329,5	378225	542,89
30	620	26,7	16554	384400	712,89
31	625	27,3	17062,5	390625	745,29
32	630	30	18900	396900	900
32	635	30,7	19494,5	403225	942,49
33	640	35,3	22592	409600	1246,09
35	600	17,7	10620	360000	313,29
33 36	610	17,7	11590	372100	313,29
30	605	19	11390	366025	361
38	615	22,7	13960,5	378225	515,29
<u>39</u>	620	27	16740	384400	<u>729</u>
40	625	29	18125	390625	841
41	630	30,3	19089	396900	918,09
42	635	32	20320	403225	1024
43	640	35	22400	409600	1225
44	645	37,3	24058,5	416025	1391,29
45	630	30,3	19089	396900	918,09
46	600	16,3	9780	360000	265,69
47	640	34,7	22208	409600	1204,09
48	620	26,7	16554	384400	712,89
<b>49</b>	640	35,7	22848	409600	1274,49
50	1	36,7	23855	422500	1346,89
sum	650	<u> </u>	424106	9721225	19452,33

Table 2: Calculations for correlation and regression analysis



The calculated value for the coefficient of correlation indicates a high proportional linear correlation between the average knitting speed and the tearing of the thread, i.e. the occurred defects. The conclusion is that exists a linear correlation between the two variables, with a confidence level of 99,9 %. The regression coefficient gives the estimate of the dependence of the defects on the speed of the knitting machine. Based on these calculations, a regression diagram between the defects (tearing of the thread) and the knitting speed of the circular knitting machine are presented in Figure 2.



### CONCLUSION

Figure 1 and 2: Regression between knitting speed and occurred defects

For the first set of machine speed, with increasing of knitting speed from 540 to 595 rpm, the number of defects reduces. For second set of machine speed, with increasing the machine speed from 600 to 650 rpm, the number of defects increases. The regression coefficient indicates that 98 % of the points lie close to the regression line. As the knitting process is a complex production process where many factors and correlations exist, optimum machine speed should be determined, resulting in stable process, lower production costs and increased productivity.