

The application of FMEA to reduce defective rate from broken filament defects in the Direct Spin Drawing process

Parinee Kaewsom¹, Napassavong Rojanarowan²

¹(Department of Industrial Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand. Parinee.k@student.chula.ac.th)

²(Department of Industrial Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand. Napassavong.o@chula.ac.th)

Abstract: -This paper presents a methodology to reduce defective rate from broken filament defects in the Direct Spin Drawing process. The Failure Mode and Effects Analysis (FMEA) was used to analyze the causes of defect and prioritize those causes, leading to the pertinent improvement methods. The improvement method involved the development of better methods for detection of failures occurred in machine parts. After improvement, the defective rate from broken filament defects significantly was reduced from 3.35% to 1.76%.

Keywords: -Broken filament, Defective Reduction, Direct Spin Draw process, Detection, FMEA

I. INTRODUCTION

Yarn is used in the manufacture of seat belt used in a vehicle. Yarn consists of many filaments. Broken filament was a major defect commonly found in producing the yarn. A sheet of yarn was considered as defective when there were two or more broken filaments per sheet. In the case study factory, the defective rate from broken filament defects was 3.35%, which was 62.4% of the total defects. There were many possible factors, which can cause the broken filament defect. These factors were mainly machine-related. Thus, there was a need to identify the major root causes and solve them to obtain the lower defective rate.

II. LITERATURE REVIEW

The mechanical properties such as the stretch of the yarn, the tension of the yarn, and the friction between the yarn and the machine could cause the broken filament defect. The tension of the polyester yarn was related to the setting of machine factors such as the spinning temperature, the velocity at the spinneret outlet, the temperature of quench air, the velocity of quench air, and the spinning velocity [1]. The spin pack cleaning was important since a dirty spinneret hole will result in uneven polymeric liquid flow through the spinneret hole [2]. Furthermore, the parameters influencing the quality of the modern fiber draw process were the fiber radius, the draw speed, and the draw tension [3]. Moreover, the parameters in the spinning and the drawing processes also affected the quality of the yarn. These parameters were the spinning speed, the spinning temperature, the speed of the Godet roller, the winder speed, and the steam pressure. The speed of the Godet roller directly affected the draw ratio, the tenacity, the elongation, and the shrinkage ratio [4]. There were many factors that could cause the broken filament defect. However, solving all the causes was not cost-effective. Thus, there is a need to prioritize the causes and improve on important factors. Thus, this research has the aim to investigate all possible factors in the Direct Spin Draw process and prioritize those causes to obtain important factors to be improved.

Failure Mode and Effect Analysis (FMEA) is a technique for evaluation of potential failure modes and their effects, the causes of the failure modes and its occurrence rates, and also the detection methods and their effectiveness. The consequences of FMEA development are to prevent or reduce the severity of failures, to detect the cause of failure by starting with highest-priority ones [5]. A knitting company used FMEA as a tool to analyze the important causes and then to find solutions for further improvement [6].

III. PRODUCTION PROCESS OF YARN

The Direct Spin Drawing process (DSD) starts when the dry chip is melt into the polymeric liquid. Then, it is compressed through the spiral of the extruder. Next, the polymeric liquid flows through the heating box and the spin box, and then is compressed through the metering pump. After that the polymeric liquid is compressed through the spinneret holes to form the filaments. Next, the filaments are cooled by the quenching air and combined to form the yarn by a suction gun. Next, the yarn passes into the drawing zone, which helps stretch the yarn. In the drawing zone, the yarn passes through 5 Godet rollers. Each roller might have different temperature and speed. Between some of the rollers, there was an air guide to blow and form the yarn with

pressure. After the yarn passes through all rollers, the yarn is rolled into a paper tube and is inspected before being sent to the customers.

IV. METHODOLOGY

First the FMEA team was set up. Then, the team applied the concept of the criteria of FMEA to prioritize the causes to be improved. These criteria are the severity rating of the failure mode effects, the occurrence rating of failure causes, and the detection rating of the effectiveness of the detection methods [7]. The FMEA criteria of AIAG [7] are commonly used in automotive and electronics industries. However, there is no FMEA criteria particularly developed for the textile industry. Thus, this research has developed the description of the FMEA score rating to be properly used in the case study company, which is in the textile industry. This research has developed the description of score rating for two criteria, which are the occurrence rating and the detection rating. The description of the severity rating was not developed since in this case, there is only one type of defect under consideration. The severity ratings of all failure modes are the same, which is 9 (filaments broke). The description of the developed score rating is shown in Table 1. Next, the team used the risk priority number (RPN), which is the multiplication of the severity rating, the occurrence rating, and the detection rating to prioritize the failure causes. The causes with higher RPNs were considered as the more important causes, which would be selected and solved further.

Table 1 The description of the developed occurrence rating and detecting rating

Score	Occurrence Scale	Detection Scale
10	Everyday	No inspection
9	Every 3-6 days	Inspection when there is complaint
8	Every 1-2 weeks	Inspection occasionally
7	Every 3-4 weeks	Periodic visual inspection on some machines
6	Every 1-2 months	Periodic visual inspection on all machines
5	Every 3-6 month	Regular inspection with simple visual check
4	Every 7-12 months	Check with measuring instrument and monitor with control chart. Then, take action when extreme point is found
3	Every 1 - 2 years	Check with measuring instrument and monitor with control chart. Then, take action when sensitivity rules are violated
2	Every 3 - 4 years	100% inspection by automatic system with no alarm system
1	More than 4 years	100% inspection by automatic system with alarm system

V. RESULTS

After defining the criteria for FMEA analysis, then the team brainstormed to list out all potential failure modes, failure causes, and related detection methods according process functions. Then, the score ratings were given. Table 2 shows the score rating of 10 failure causes which have the highest RPNs. Out of these 10 failure causes, there are 8 causes that were improved by changing the detection method or determining more appropriate detection frequency. The causes related to parameter setting were suggested to be studied further using the design of experiment technique to help find the optimal setting.

Table 2FMEA Analysis and improvement solutions

Process Function/ Requirements	Potential Failure Mode	Potential Effect(s) of Failure Mode	S	Potential Cause(s)/ Mechanism(s) of Failure	O	Current Control		D	R P N	Recommended Action(s)	Responsibility & Target Completion Date	Actions Result				
						Prevention	Detection					S	O	D	R P N	
Air Guide shakes off oil from yarn and form yarn together	Yarn position in Air Guide holes is not centered.	Yarn swings and scratches with Air Guide, leading to broken yarn.	9	Nuts of Air guide are loosening.	9	-	Inspect position of yarn in Air Guide holes when there is complaint	9	7 2 9	Check nuts every 2 days and check the center of yarn every shift.	Process Engineer (20/7/2013)	Check nuts every 2 days and check the center of yarn every shift.	9	6	5	2 7 0
	The balloon of yarn is bad.	Yarn has bad balloon. Then, it swings and scratches with Air Guide, leading to broken yarn.	9	Holes of Air Guide are dirty.	8	Holes of Air guide are inspected longer than once a week by visual check.	Inspect balloon of yarn when there is complaint	9	6 4 8	Clean Air Guide every 3 months.	Process Engineer (20/7/2013)	Clean Air guide every 3 months and check the cleanliness of Air Guide hole before using	9	5	5	2 2 5
			9	Regulator is ruined.	8	-	Inspect balloon of yarn when there is complaint	9	6 4 8	Check Air Guide pressure every shift and check regulator gauge when coating.	Supervisor (20/7/2013)	Check Air Guide pressure every shift and check regulator gauge when coating.	9	7	5	3 1 5

Table 2FMEA Analysis and improvement solutions (Cont.)

Process Function/ Requirements	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s)/ Mechanism(s) of Failure	O	Current Control		D	R P N	Recommended Action(s)	Responsibility & Target Completion Date	Actions Result				
						Prevention	Detection					S	O	D	R P N	
Godet Roller (GR) stretches yarn and guide yarn through yarn path.	Yarn is too tight or too slack.	Too tight yarn is easily broken. Too slack yarn can scratch with machine parts, leading to broken yarn.	9	Inappropriate speed setting.	8	Recheck speed setting every 8 hours.	Inspect yarn occasionally	8	5 7 6	Perform design of experiment to test and find appropriate speed setting.	Production Engineer (28/7/2013)	Perform design of experiment to test and find appropriate speed setting for each Godet roller.	9	7	3	1 8 9
	Yarn is too soft.	Too soft yarn stretches less and difficult to guide, leading to broken yarn.	9	Inappropriate temperature setting.	8	Recheck temperature setting every 8 hours.	Inspect yarn quality occasionally	8	5 7 6	Perform design of experiment to test and find appropriate temperature setting.	Production Engineer (28/7/2013)	Perform design of experiment to test and find appropriate temperature setting for GR1, GR2.	9	7	3	1 8 9
	Godet Roller is cracked or scratched	Yarn passes through cracked or scratched GR surface, leading to broken yarn.	9	Yarn always passes through the same position on GR.	6	Check the GR surface longer than once a month	Inspect GR surface occasionally	8	4 3 2	Create standard for checking GR surface every 2 weeks and changing the GR.	Production Engineer (28/7/2013)	Create standard for checking GR surface every 2 weeks and changing the GR.	9	6	7	3 7 8
	Godet roller is dirty.	Yarn which passes through dirt gets stuck and scratched, leading to broken yarn.	9	Cleaning method is ineffective and cleaning frequency is not appropriate.	9	Check the cleanliness of GR every day but no criteria for deciding whether the roller is clean or not.	Inspect the cleanliness of GR when there is complaint	9	7 2 9	Create photos of GR surface before – after cleaning and use it as a standard for inspection.	Production Engineer (28/7/2013)	Create photos of GR surface before – after cleaning and use it as a standard for inspection.	9	8	5	3 6 0

Table 2 FMEA Analysis and improvement solutions (Cont.)

Process Function/ Requirements	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s)/ Mechanism(s) of Failure	O	Current Control		D	R P N	Recommended Action(s)	Responsibility & Target Completion Date	Actions Result				
						Prevention	Detection					Actions Taken	S	O	D	R P N
Winder spins yarn into tube.	Hanetora and Wave guide are in wrong position.	Yarn scratches with Hanetora and Wave guide, leading to broken yarn.	9	Broken filament on yarn made Hanetora and Wave guide move.	7	-	Check the position of Hanetora and Wave guide when there is complaint	9	567	Check the position of Hanetora and Wave guide every 2 weeks	Maintenance (10/7/2013)	Check the position of Hanetora and Wave guide every 2 weeks.	9	7	6	378
	Roller Bail is scratched	Yarn rubs with scratched Roller Bail, leading to broken yarn.	9	Cutter which is used to cut broken filament scratches on the Roller Bail.	7	-	Periodically visual inspect Roller Bail surface of all machines every 2-7 days.	6	378	- Use heater cutter instead. - Make standard for checking scratch and check every 2 weeks to help decide on Roller Bail changing time.	Maintenance (10/7/2013)	- Use heater cutter instead. - Make standard for checking scratch and check every 2 weeks.	9	8	5	360
	Hanetora and Wave guide surface are scratched	Yarn rubs with scratched Roller Bail, leading to broken yarn.	9	Hanetora and Wave guide are used for a long time.	6	-	Periodically visual inspect Roller Bail surface of all machines every 10-14 days.	6	324	Make standard for checking scratch and check every 2 weeks to help decide on Hanetora and Wave guide changing time.	Maintenance (10/7/2013)	Make standard for checking scratch and check every 2 weeks.	9	6	5	270

VI. SUMMARY

This paper presents a methodology to reduce the defective rate from broken filament defects in the Direct Spin Drawing process by using the Failure Mode and Effects Analysis (FMEA) technique. FMEA helps analyze and prioritize the important failure causes to be improved further. After the FMEA analysis, the selected causes were grouped into two groups. Group 1 involves the causes, which were improved by the changing the detection methods or determining more appropriate detection frequency. Group 2 involves the causes related to the machine parameter setting, which suggested to be further improved by the use of the design of experiment technique. After improving the detection method, the defective rate from broken filament defects was reduced from 3.35% to 1.76%.

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