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REDUCING COIL BREAK REJECTION AT HOT SKIN PASS MILL PT KRAKATAU STEEL

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Abstract—*Coil break rejection at Hot Skin Pass Mill PT Krakatau Steel is a repetitive claim from consumer and target of quality objective is still out of target. Coil break is surface defect of hot rolled coil with appearance of surface looks some areas of small lines transverse to rolling direction, low contrast to surface white or black lines. Lower yielding point of the hot rolled coil tends to have coil break rejection. Hot Skin Pass Mill (HSPM) is dedicated to prevent coil break. Anti Coil Break is the equipment at the entry section of HSPM which has main function to prevent coil break. If this equipment works properly then coil break rejection on the surface of strip can be prevented. Engineering, operation, and organization category can influence the rejection. Engineering : Anti Coil Break parameter, inspection of equipment, and quality of strip inspection. Operation: Adjustment of Finishing Temperature-Coiling Temperature and operation parameter HSPM. Organization : Span of control too wide and organization alignment. Each factor will be analyzed by Root cause analysis find the root of problem. Each category of engineering, operation, and organization will be analyzed to recommend as implementation plan. Alternative solutions proposed are : improvement of equipment reliability, redesign Anti Coil Break Roll, implementation of Statistical Process Control, review Quality Product Level, empowerment of structures, and alignment of organization. Each alternative was evaluated to propose as implementation plan. Implementation plan consists of the mandatory plan or the highest priority of each category.*

Keywords : coil break, PT Krakatau Steel, hot rolled coil, yielding point, finishing temperature, coiling temperature.

1. Introduction

PT Krakatau Steel (PTKS) is the first and the biggest integrated steel at Indonesia. Steel quality is the main concern of PTKS and the quality is better than the competitor at Indonesia. At the end of 2011, PT Krakatau Steel got coil break claims from consumer. Coil break is surface defect. The appearance of surface looks some areas of small lines transverse to rolling direction. This appearance often with low contrast to surface white or black lines, as indicated at Figure 1.

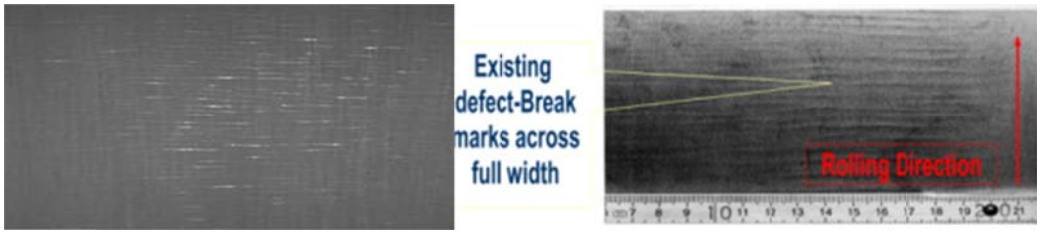
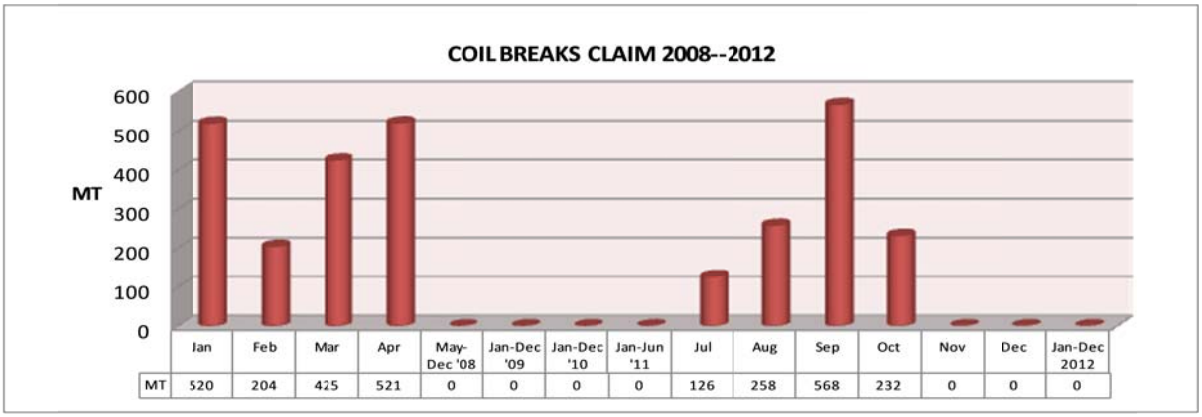


Figure 1. General Appearance of Coil Break

1.1 Repetitive Claim

Looking back at the history of HSPM, it was very interesting that this claim was already happened on 2008. This claim came from the same consumer, Papajaya, Hamasa, and Lion Metal Works.



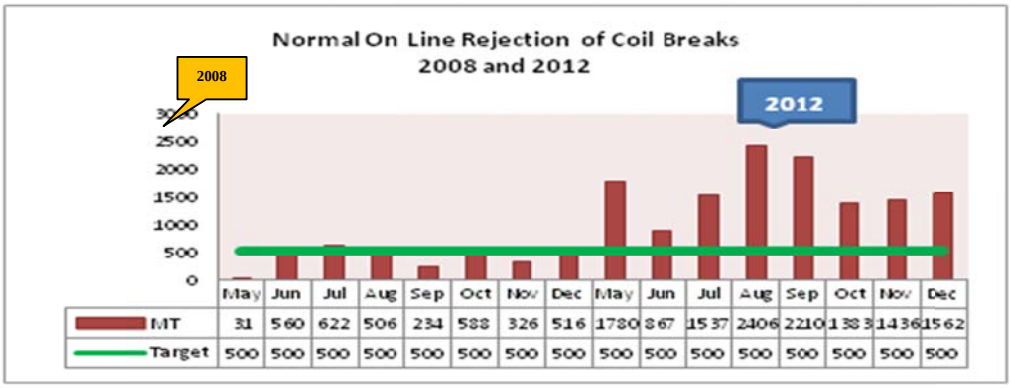
	Jan	Feb	Mar	Apr	May-Dec '08	Jan-Dec '09	Jan-Dec '10	Jan-Jun '11	Jul	Aug	Sep	Oct	Nov	Dec	Jan-Dec 2012
MT	520	204	425	521	0	0	0	0	126	258	568	232	0	0	0

Figure 2. Coil Break Claim 2008 and 2011

Some corrective actions done in 2008 and rejection was reduced significantly then the claim was disappeared. In 2011 this claim came again from the same consumer. Although HSPM always can overcome the coil break rejection problem but repetitive claim is still potential problem.

1.2 Quality Objective

Online coil break rejection always happen even in the normal condition. This online coil break rejection sometimes is out of target.



	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MT	31	560	622	506	234	588	326	516	1780	867	1537	2406	2210	1383	1436	1562
Target	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500

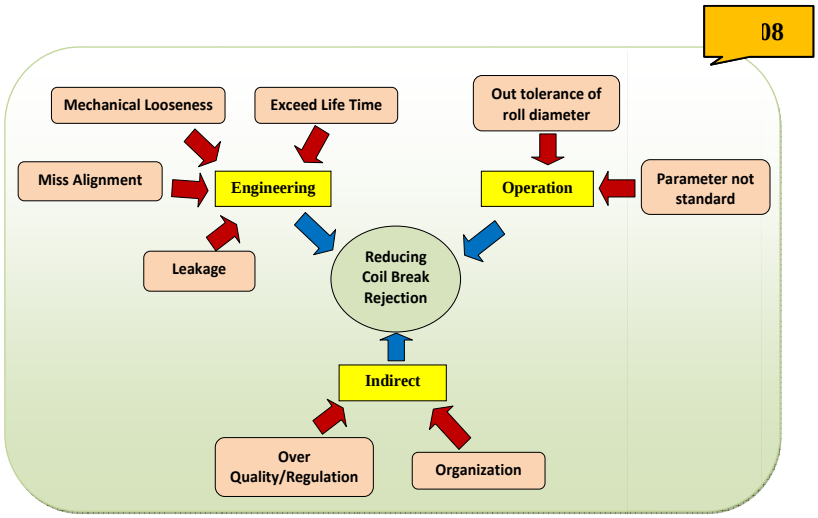
Figure 3. Normal Online Coil Break Rejection at HSPM 2008 and 2012

The level of target is 1% per month, it is around 500 MT per month. Normal online rejection means rejection without claim condition. The normal online rejection in period 2008 and 2012 can be seen at Figure 3.

2. Business Exploration

2.1 Conceptual Framework

Conceptual frame work is the first step to identify coil break claim or rejection and to define what defect actually happen, and at the end will give basic frame work to solve the issue. Figure 4. is the conceptual framework to analyse what factors can influence the coil break rejection.



Paul, Ahmed, and Megaheed, 2010, stated that operational factor such as rolling parameter at HSM can influence coil break rejection at HSPM. *Watanabe, 2005*, stated that engineering and operational factor at HSPM, will strong influence to coil break rejection. Some equipment related to surface of strip at HSPM was suspected not in the standard condition. It might be some miss alignment, over clearance, mechanical looseness, or some parts exceeded the life time. Leakage at hydraulic system can influence also the pressure, the pressure will be fluctuation.

2.1.1 Yielding and Cooling Rate

Refer to the *Megahed*, *Hsun H, and Sober*, coil breaks is the surface defect which is the result of local yielding phenomena and uncoiling problem. This local yielding will cause crease or ridge on the surface of the strip forming irregular interval and parallel. This crease, ridge, or line marks is perpendicular to the rolling direction.

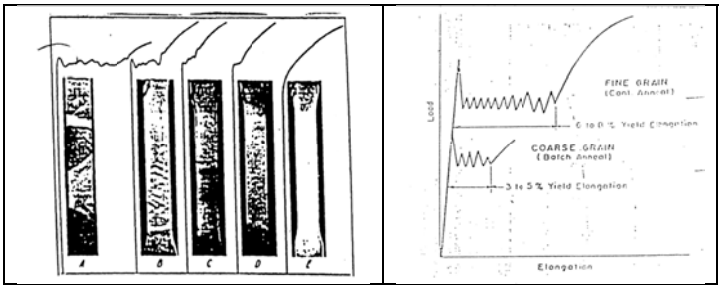


Figure 5. Yield Point Elongation and Coil Break

This yielding phenomena is caused by inhomeginity of microstructure.Then this inhomogenity of microstructure is affected by reduction, cooling rate, and chemical element contained in the steel, as indicated at Figure 5.

2.1.2 Parameter of HSPM

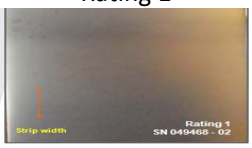
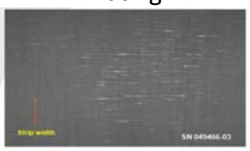
Coil breaks occur transverse to the rolling direction when uncoiling and appear at irregular interval. It results from the presence of a yield-point elongation attributtable yo insufficient hot skin pass rolling and uncoiling parameter. All of Hot Skin Pass Mill in the world always installs Anti Coil Break Roll or Pressure Roll to eliminate coil breaks defect, such as Blue Scope Steel, Essar, and also Hot Skin Pass Mill at Krakatau Steel. Some HSPM parameters besides anti coil breaks practices have to be considered to eliminate coil breaks defect. These parameters are entry tension, exit tension, pressure of anti coil break roll, speed process, and roll force.

2.1.3 Problem Identification

A. Rating of Coil Break

After evaluating the case of online rejection due to coil break period November-December 2011, acquired defect rating. Rating 1 and 2 are acceptable , while rating 3 and 4 can not be accepted by consumers. Here is the rating classification at Table 1 :

Table 1. Rating Classification of Coil Break Rejection

Rating 1  ➢ No break line marks Accepted by Consumer	Rating 2  ➢ Small break line marks Accepted by Consumer
Rating 3  ➢ Break line marks Not accepted by Consumer	Rating 4  ➢ Heavy break line marks Not accepted by Consumer

B. Product Specification Rejected

Upon closer investigation found that not all of the products processed at HSPM would have coil breaks defect. Only products by grade SPHC, BJPC, and SPHT1 have suffered coil breaks. Here are the product specifications of coil break rejected, as seen at Table 2.

Table 2. Product Specification of Coil Break Rejected

No.	Description	SPHC	SPHT1	BJPC
1	Equivalent Material	JIS G 3131	JIS G 3132	SNI07-0601-2006
2	Internal Grade	OA0603 OA0804	OA0603 OA0804	OA0603 OA0804
3	Tensile Strength (N/mm^2)	270 (min)	270 (min)	270 (min)

This was the dominant product of HSPM as seen at Table 3.

Table 3. Production Volume at HSPM (2009-2012)

Product Specification	2009 (MT)	2010 (MT)	2011 (MT)	2012 (MT)
SPHC	182.556	190.214	176.943	184.881
BJPC	126.860	132.999	169.047	177.519
SPHT1	47.078	62.568	73.454	78.183
Others	133.887	97.850	89.387	77.872
Total	490.381	483.631	508.831	518.456

The application of this product is for commercial quality, such as pipe and tube, construction, office and home appliance.

2.2 Analysis of Business Situation

2.2.1 Existing Operation Parameter

Here are the relevant parameter processes at HSM to produce SPHC, SPHT1, and BJPC in relation to coil break rejection analysis as described at Table 4:

Table 4. Operation Parameter Standard of HSM

Item	Unit	Parameter
Product Specification		SPHC, BJPC, and SPHT1
Reheating Furnace	^{0}C	1220 -1250
Finishing Temp. ((FT)	^{0}C	840 ± 15
Coiling Temp. (CT)	^{0}C	560 ± 10
Last Active Stand reduction at Finishing Mill	%	10 (min)

This parameter was already established since April 2008, when the coil break rejection happened at that time. *Refer to Paul, Ahmed, and Hsun Hu*, items to be analyzed at HSM relating to coil break rejection is Finishing Temperature and Coiling Temperature. Trial at 2008 explained us that FT 840 ± 15 ^{0}C and CT 560 ± 10^{0}C is appropriate to prevent coil break rejection at HSPM.

At the same time the actual operation parameter standard at HSPM is described at Table 5. This parameter was already established since HSPM operate for the first time in 1996.

Table 5. Operation Parameter Standard of HSPM

Item	**Uni**	**Thickness (mm)**	
		1.80 – 3.50	**3.55 –**
Tension at Pay Off Reel (max)	Kg	5.000	10.000
Tension at Tension Reel (max)	Kg	8.000	16.000
Speed (max)	mp	400	200
Rolling Force (max)	KN	13.000	
Bending Force (max)	KN	1.300	
Pressure of Anti Coil Break Roll	bar	100 - 120	
Different WR diam. top bottom	µm	200	

Anti Coil Break Roll installed at the entry section, just after Uncoiler, is the equipment dedicated to anticipate coil break rejection. This equipment must operate well at any time so the condition must be perfect to reach the pressure determined.

2.2.2 Existing Quality Regulation

It is not all HSM product will be sent to HSPM, only around 30% of that being processed at HSPM. Material Product Development (MPD) Department has been already recommended which product must be processed at HSPM according to consumer requirement and product specification, as described at Table 6. This quality regulation is dedicated to improve flatness problem and prevent coil break rejection. This quality rejection has already implemented since 1999, 3 years after HSPM operated at the middle of 1996.

Table 6. Regulation of HSPM Product

Product	Dimension (mm)		Spec. Code
	Thickness	Width	
HRC	t ≤ 2.10	All	All
	2.11≤ t ≤ 3.99	W ≤ 1550	SPHC (series), BJPC, SPHT
	2.11≤ t ≤ 7.00	W ≤ 1550	SAE1006PO, SAE1008PO, SAE1010PO
	t ≤ 6.00	W ≤ 1550	HSAPH440, HSAPH540, HSAPH620
HRPO	t ≤ 2.10	All	All HRPO Spec.
	2.11≤ t ≤ 6.00	W ≤ 1250	All spec. code at No. 2, 3, and 4

All HRPO products must be processed at HSPM because this product is very sensitive to flatness problem and coil break rejection. It is around 73-85% of HSPM is SPHC series, BJPC, and SPHT, as seen at Table 3.

2.2.2 Implementation of Standard Operating Procedure

In general the implementation of Standard Operating Procedure at HSM was almost be followed by operator, because all parameter was controlled automatically by system, by machine. It was only in some little cases operator can make intervention into the system, but after this intervention, maintenance staff will be fixed this problem and the system will be back into automatic mode.

At HSPM too many standard can be interrupted by operator, because this HSPM not fully controlled automatically by machine. Some of operation standard was not implemented at HSPM in December 2011, as indicated at Table 7.

Table 7. Actual Operation Parameter of HSPM in December 2011

Item	**Unit**	**Thickness (mm)**		**Actual**
		1.80-3.50	**3.55 – 7.00**	
Tension at Pay Off Reel (max)	Kg	5.000	10.000	Ok
Tension at Tension Reel (max)	Kg	8.000	16.000	Ok
Speed (max)	mpm	400	200	**Not Ok**
Rolling Force (max)	KN	13.000		Ok
Bending Force (max)	KN	1.300		Ok

Pressure of Anti Coil Break Roll	bar	100 - 120	100 - 120	**Not Ok**
Different WR diam. top bottom	µm	200		**Not Ok**

The worst condition at that time the maximum speed was only 40 mpm, it means only 10% of maximum speed design. Pressure of anti coil break roll was fluctuation, sometimes pressure drop to 60 bar. It should be hydraulic problem happen at this system. This pressure fluctuation cause using of anti coil break was not optimum. Basically this stable pressure controls the elongation upon the strip being processed. Different work roll diameter top bottom not consistent, sometimes different diameter was more than 200 µm, even can get close to 1.000 µm at the worst condition. All this parameter can generate the coil break rejection at HSPM.

2.2.3 Corrective Action Done to Overcome Coil Break Rejection

A. Period 2008

When coil break claim happened in 2008, all of corrective actions done was at HSM due to yielding phenomena. As literature noted, that yielding phenomena can generate the coil break rejection at HRC. It would be more sensitive to coil break rejection. Yielding phenomena can control by adjusted FT, CT and reduction. All parameter, as noted at Table 8, could be achieved by HSM. There is no fixing equipment problem at HSPM but some operation standard did not implement consistently as seen at pressure of anti coil break and different work roll diameter. Task force team then gave socialization in order to implement the HSPM operation standard consistently, especially in implementation different work roll diameter and utilization of anti coil break roll.

Table 8. Parameter of HSM in 2008

Item	Unit	Parameter	Actual
Reheating Furnace	^{0}C	1200 -1220	Ok
Finishing Temp. ((FT)	^{0}C	840 ± 15	Ok
Coiling Temp. (CT)	^{0}C	560 ± 10	Ok
Last Active Stand reduction at Finishing Mill	%	10 (min)	Ok

B. Period 2012

Looking at Table 10, at HSPM the main issues is engineering problem. Hydraulic pressure not stable, pneumatic system problem, vibration too high at roll drive, over clearance, roll not standard, and unrecorded tension. That engineering problem coming from entry section to exit section, it means almaost each section of HSPM get problem. It can be concluded that this HSPM is poor maintenance, and preventive maintenance done not dicipline. If daily or shiftly inspection doing properly and reported to planning and preventive maintenance departments, than this department can organize properly the preventive maintenance. Mechanic and operation loose control on HSPM area, because almost engineering problems are coming from mechanic and operation. Only 1 item is electric problem, that is unrecorded tension.

Internal leakage, over clearance, different diameter too high, not alignment, dirty oil and hydraulic system are engineering and operation problem at HSPM. These problems shows that HSPM is not proper maintenance and inspection. Based on literature, yielding phenomena can be approached by cooling rate. Lowering FT and CT at that temperature can reduce yielding problem but it will cause operational problem at HSM. Because FT 820 ^{o}C is too low so it can affect to vibration at the stand of finishing mil.

Table 10. Corrective Action Done at HSPM in January 2012

What	Where	Why	Who	How
Hydraulic Pressure not stable	Pressure Roll (Anti Coil Break)	Internal Leakage	ME	Replace cyl. & seal Replace servo and filter
		Bad Valve	ME	Repair and replace valve
	Auxilliary tank	Accumulator Dirty	ME ME	Increase pressure Flushing the pipe and replace the oil
Pneumatic system problem	Pinch Roll 3	Wear Cylinder	ME	Replace cylinder pneumatic
	Separator	Mixed by oil	ME	Fixed the leakage and cleaning the separator
Vibration too high at Roll Drive	Bearing Cross Joint	Not standard	ME	Replace bearing cross joint
	Wobler Plate	Over clearance	ME	Replace liner
	Gear Box	Back lash	ME	Check back lash
	Spindle	Not Allign	ME	Check, corrective, and allignment
Over Clearance	Mill Stand	Over Clearance	ME	Fix the wear plate
	Entry Coil Car	Over Clearance	ME	Add the shim plate
	Pay Off Reel	Over Clearance	ME	Add the shim plate
	Chock WR	Over Clearance	OP	Add the wear plate
Roll not standard	Work Roll	Over Diameter	OP	Diameter top n bottom almost similar
	Anti Crimping Roll	Bad surface	OP	Replace anti crimping roll

	Pressure Roll	Profile Out	OP	Replace the roll
Unrecorded Tension	Loss Comm"tion	Server fault	EL	Install New Server

Note : ME: Mechanic, OP: Operation, EL : Electric

2.3 Root Cause Analysis

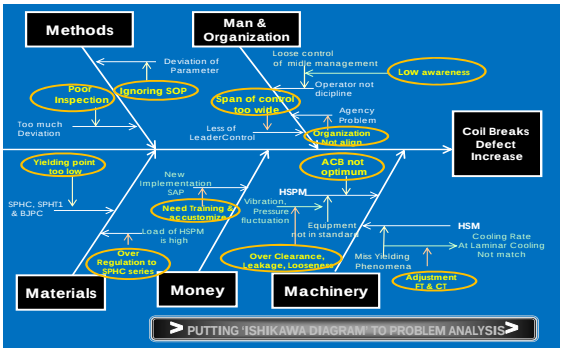


Figure 7. Root Cause Analysis of Coil Break Rejection

The yellow circles at Figure 7. are the root of problem.

Table 12. Classifying the Root

Root of Problem	Evidence	Class
Equipment not standard	Over Clearance, Leakage, Looseness	Engineering
Poor Inspection	Too much deviation	
ACB not optimum	Reliability is not good	
Over Regulation	HSPM overload	Operation
Adjustment FT & CT	Yielding points too Low	
Low Awareness	Parameter deviation	Man Power
Ignoring SOP	Low discipline	
Need Training and accustomed	Know how problem	
Control span too wide	Loss control from leader	Organization
Organization not align	Agency problem	

Note : Man power and organizational is indirect factor.

After classifying the root of problem in RCA, found that 4 classes of issue : engineering, operational, and indirect factor. Indirect factor consist of man power and organizational. It will take a long time to

solve man power problem, because it will be too much department get involved in man power problem. It is not only production directorate but also human capital directorate. All of roots are listed then evaluate each subject listed refer to main class available, as seen at Table 12.

3. Business Solution

a. ALTERNATIVE SOLUTION OF ENGINEERING AT HSPM

3.1.1 Improvement of Equipment Reliability

Equipment reliability must be improved to guarantee all the equipment running as per manual operation. If the range pressure of anti coil break roll is 100-120 bar then the equipment cannot achieve this range of pressure, do not operate the HSPM and fix the equipment first. If tolerance was given for 99 bar then some day will be given the tolerance of 98 bar, because the reason is no significant effect.

Inspection done by HSPM maintenance staff was included : cleanliness, looseness, greasing, lubricating, clearance, wear, vibration, diameter, and over life time. Improvement of Inspection can be seen at Table 13.

Table 13. Correction of Inspection Schedule at HSPM

Equipment	Inspection	Freq.		Tool
		Now	*Next*	
ACB Roll	Check pressure	daily	***shiftly***	**PG**
Auxiliary Tank	Check pressure	daily	***shiftly***	**PG**
Pinch Roll	Check pressure	daily	***shiftly***	**PG**
Separator	Check leakage	daily	***shiftly***	**V**
Bearing Cross Joint	Check current	6 months	***monthly***	**HMI**
Wobbler Plate	Check vibration	6 months	***monthly***	**C**
Gear box	Check back lash	6 months	***3 months***	**DI**
Spindle	Check alignment	6 months	***3 months***	**T**
Mill Stand	Check vibration	yearly	***6 motnhs***	**CS**
Entry Coil Car	Check current	3 months	***monthly***	**HMI**
Pay Off Reel	Check current	3 months	***monthly***	**HMI**
Chock WR	Check Force	3 months	***monthly***	**HMI**

Work Roll	Check Diameter	daily	***shiftly***	**OM**
Anti Crimping Roll	Check surface	month ly	***weekl y***	**V**

PG : Pressure Gage V : Visual HMI : Human Machine Interface
C : Caliper T : Theodolite CS : Caliper Stick OM : Outside Micrometer
Red : Proposed

The red letter indicated an improvement of inspection frequency and tool must be provided for inspection. Tool for inspection is a mandatory provided by supervisor. Inspection cannot be done perfectly without tool. This inspection standard must be implemented strictly and supervisor must check and evaluate the result of inspection daily.

3.1.2 Redesign of Anti Coil Break Roll

Figure 10 is new design of anti coil break roll recommended, consist of work roll and back up roll. This figure is designed by SIEMENS-VAI, Austria. Work roll is smaller roll directly touch the strip, and back up roll is bigger diameter and supporting the work roll.

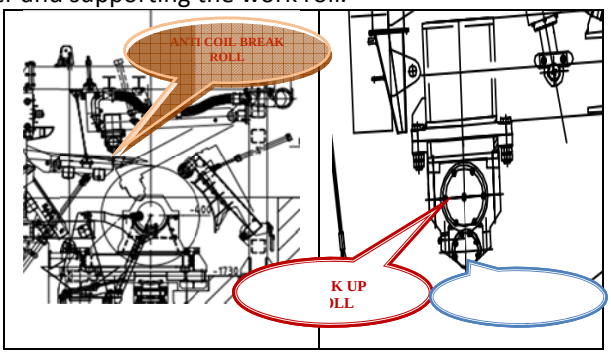


Figure 10. New Design of Anti Coil Break Roll

Work roll of new design is smaller than roll of old design. Smaller diameter roll can press the smaller of surface area of strip then the stretch-strain become smoother. So yielding point can be improved by smaller diameter of roll, and the coil break can be prevented. New design of ACB Roll system is completely. It is not only mechanic, but also hydraulic system.

3.2 Alternative Solution of Operation

3.2.1 Implementation of Statistical Process Control

In case of adjustment parameter FT and CT, there is two different recommendation to operator : In 2008, MPD department gave recommendation FT 840 ± 15 ^{0}C and CT was 560 ± 10 ^{0}C, but for the same case at 2012 he gave recommendation FT 820 ± 15 ^{0}C and CT was 520 ± 10 ^{0}C. It was made unclear for operator. Different view between operation and quality control cause unclear parameter should be used at the HSM.

By implementing statistical process control (SPC) this issue can be evaluated more accurate. Process and operation parameter at HSM and HSPM were controlled more detail and compare to final quality.

3.2.2 Quality Product Level

Quality product level is the regulation of PTKS to match quality requirement of consumer and process route at PTKS. Quality level of each consumer is different. HRC for automotive is different level quality with HRC for commercial structure. This Quality requirement will determine the process level and process route at PTKS. By reviewing quality product level, load of HSPM can be reduced.

Looking at Table 14, this is not normal, satisfying the consumer beyond their quality requirement. More than 99% is without any requirement order of consumer. This value is too much, and PTKS must review internal quality regulation, whether it was over quality treatment.

Table 14. Annual Order and Production of HSPM 2011-2012

Year	Total Production (MT)	Total Order (MT)	Consumer requirement (MT)	% cons. req to tot.order
2011	508.831	445.971	3.290	0.7%
2012	518.456	478.064	2.040	0.43%

PTKS can develop new regulation by evaluating existing regulation. Not all SPHC and BJPC for thickness 2.11≤ t ≤ 3.99 and W ≤ 1550 require perfect strip flatness quality. PTKS can follow Table 15 to meet appropriate regulation. Table 15 has potential opportunity to reduce 64.000 MT of HSPM annual and can convert to 1.5 month for maintenance.

Table 15. New Quality Order Regulation Proposed of HSPM Product

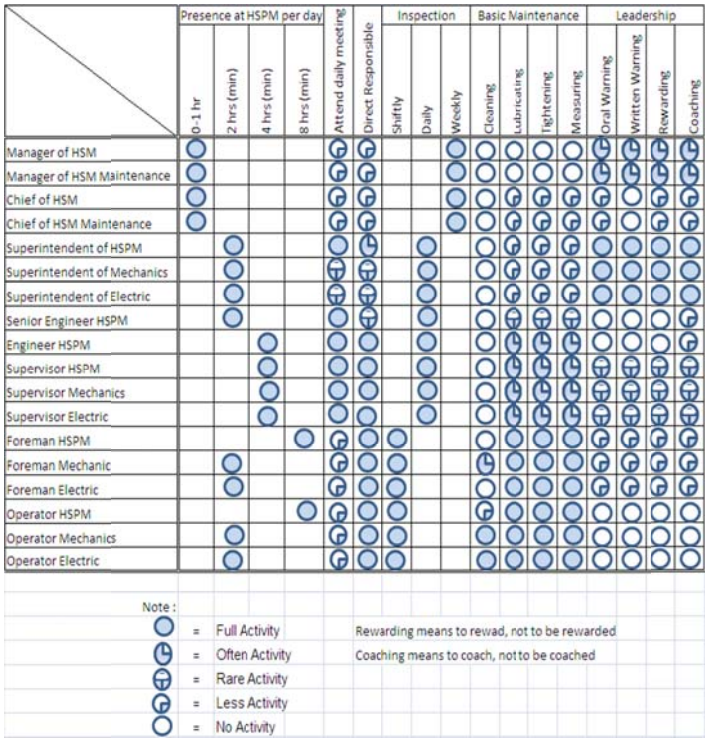
Product	Dimension (mm)		Spec. Code
	Thickness	Width	
HRC	2.11≤ t ≤ 3.00	W ≤ 1550	SPHC (series), BJPC
	3.01≤ t ≤ 3.99	W ≤ 1219	

3.3 Alternative Solution of Organizational

3.3.1 Empowerment of Structure

It is strong recommended for each position at HSPM to be closer to the HSPM. It is very important to maintain attendant time in the mill, not in the office, in order to be closer to the real condition. The standard activities of each position can be seen at Table 16.

Table 16. Standard Activities to be Done by Each Position



It needs strong superintendent to exercise good leadership for reward, punishment, and coaching. Superintendent also practices daily inspection, attend daily meeting, and the organization needs the presence of superintendent at HSPM 2 hours daily minimum.

3.3.2 Alignment of Organization

Manager of HSM Operation, Manager of Quality Control, and Manager of Material and Product Development have to discuss the alignment of organization among them to eliminate the unclear condition during rolling SPHC at HSM. Which FT-CT for SPHC product will be implemented in rolling's program. Manager of HSM should be strong recommended as a leader of this alignment because he is the final determinant of rolling schedule and he has to save the mill and the product directly. Direct participation of senior engineer MPD, engineer MPD, and Senior Engineer of Quality Control must be improved to get accurate information.

4. Conclusion and Implementation Plan

1. For the short period and to control budget tightly, improvement of equipment reliability is the best solution for engineering alternatives.
   Overhaul 2013 will be held in April 2013. This overhaul will be determinant factor to improve equipment reliability at HSPM. Corrective actions and preventive actions during overhaul must be executed appropriately.
2. For the long period and budget is enough, redesign ACB Roll is recommended also for engineering alternatives.
   This project is not mandatory. If PTKS has good space budget and time, this project is strong recommended to implement. Total time will be required to implement this project is around 3 years, since budget providing up to acceptance test. For this kind of project, since contract signed up to erection is 12 months normally. Technical discussion, detail engineering discussion, erection, and test period are the key factor to succeed of redesign of ACB.
3. Implementation of Statistical Process Control and review quality product level are a MUST to reduce coil break rejection. Both operation alternatives are a mandatory solution and can be implemented in 2013.
4. Empowerment of structure has the higher priority than alignment of organization in organization alternatives.
   The determinant stages are reposition of staff and reward-punishment. The right man on the right job and core competencies are basic requirement to select the best people to empower the structure. It will need 8 months to implement this plan.

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