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Research Article

ANALYSIS OF ROLL COOLING SYSTEM IN HOT STRIP MILL

Gemaraju Srikar [1,*]
[1,*]Department of Mechanical Engineering, Vignan's Foundation for Science, Technology and Research, Vadlamudi, Andhra Pradesh, India, PIN. 522 213

Abstract
Hot Strip Mill (HSM) in Jindal Vijayanagara Steel Limited (JVSL), Toranagallu , Bellary (Dist.), Karnataka is facing problem such as shorter campaigns, improper strip profile, reduced productivity and increased roll cost. The main cause for these problems is ineffective work roll and backup roll cooling system for roughing stands.The present work is to design the existing system in terms of number and flow rate of nozzles, nozzle angle and orientation and thermal gradient for various rolling schedules.

I Introduction

To achieve the best possible quality hot strips, the roll cooling system should be effective. Roll cooling system is the important segment that influences the effectiveness of the rolling process[1]. Inadequate cooling is the key reason for the formation of roller surface cracks. It is necessary to keep the optimal temperature on the rolls. Optimum roll cooling can be designed in two aspects [2]. The first is wearing a roll where the surface layer's strength is decreased by high temperature. The second aspect is a roll's thermal deformation. This is important for flat product form and sensitivity. Cooling sections at rolling mill should be designed with both aspects.There are so many methods to predict the distribution of heat transfer coefficient on the surface of the roll. Brno University of Technology, Crech Republic in 1988 conducted experiments for efficient roll cooling. L. Bendig, M.Raudenský [3] are conducted full-scale experiment. The full-scale experiment uses identical configuration of rows of nozzles as in rolling mill, the same pressures, velocities and coolant temperatures are used there. The cooling strength defined by the distribution of the heat transfer coefficient represents the actual conditions of the mill. An experimental method linked to numerical simulation offers a development and optimization resource of cooling.

In this project work, a method has been introduced to design an efficient roll cooling system for Jindal steel industries, Bellary. In this, nozzle orientation is changed to improve the efficiency of the system. Mass of water coolant is increased to absorb the heat from the roll surface, so that the roll life will be increased and quality hot strips can be produced from the mill. The coding has been done in Visual Basic to solve the mathematical models, so that optimal results can be selected from the coding output. With these results, using the ANSYS software comparison has been made with existing roll cooling system does analysis.

II Problem description

The purpose of the roll coolant system is to provide pressurized cooling water to the entry and delivery sides of the vertical edger rolls and delivery sides of the roughing mill work rolls. But with this roll cooling system, due to inefficient cooling, the fire cracks are formed on the surface of the roll. When the fire cracks are formed on the roll surface, the quality of the strip will be reduced. If there is an effective cooling system for rolls, the fire cracks will reduce and roll life will also increase. It is necessary to machine the roll surface frequently.

III Existing Roll system used in industry

- Water cooling system with nozzles.
- Problems facing with the existing system
  - Fire cracks on rolls,
  - Delay in roll changes and
  - Low quality of strip.

The existing rolling system is shown in figure 1. The following are the specifications of the existing roll system used in the industry

- ✓ Total heat = 14.8kw
- ✓ Mass of water = 4.2kg/sec.
- ✓ No. Of nozzles = 14
- ✓ Nozzle diameter = 2.3mm
- ✓ Nozzle angle = 20^{o}
- ✓ Temperature on roll = $85^{o}c$

IV Modeling of work roll for the existing system

The modeling of work roll for the existing rolling system used in the industry was done by using the Pro-E software is as shown in figure 2

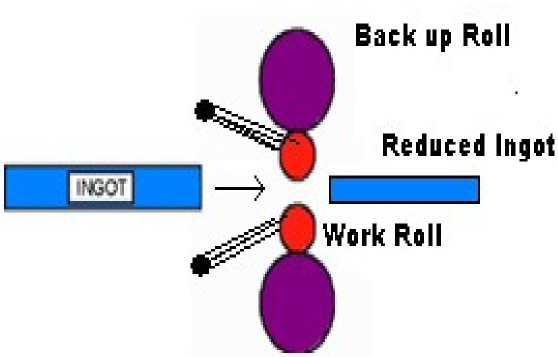

Figure 1: Rolling system used in the industry

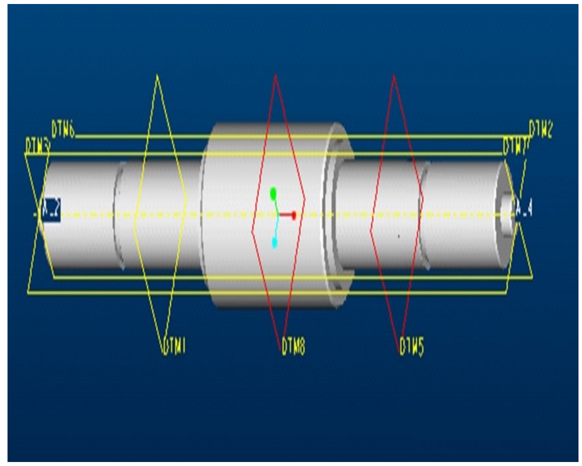

Figure 2: Modeling of work roll in Pro–E

V Heat calculations

The mathematical equations are used for heat calculations. The code written in Visual basic, so that from a number of results are obtained and best result is optimized. The code will calculate the following parameters are

1. The total heat transfer rate
2. Nozzle dimension
3. Number of nozzles
4. Mass of coolant required per second
5. Nozzle orientation (angle)
6. Spray width required on the roll surface for effective cooling

Contact surface can be calculated, as shown in the figure 3

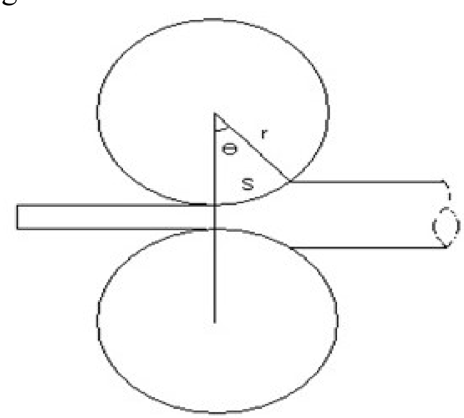

Figure 3: Contact surface between the rolls

Contact surface, $S = r \sin\theta$ ... (1)
Area of contact, $A_c = 2 \times S \times W$ ... (2)

Heat due to conduction

The amount of heat transferred from hot strip to the roller in conduction mode can be calculated by using the following formula

$Q_c = (K\ A_c\ (T_1 – T_2) / r)$ ... (3)

Heat due to radiation

The amount of heat transferred from hot strip to the roller in radiation mode can be calculated by using the following formula

$Q_r = \varepsilon \times \sigma \times A_r \times (T_1^4 – T_2^4) \times s.f.$ ... (4)

Heat due to convection

The amount of heat transferred from hot strip to the roller through air medium in convectionmode can be calculated by using the following formula

$Q_v = h \times A \times (T_1 – T_2)$ ... (5)

Grasoph number,

$Gr = (g \times \beta \times \Delta T \times L^3 \times \rho^2) / \mu^2$ ... (6)

$Nu = 0.13\ (Gr \times Pr)^{0.333}$; $Gr \times Pr < 2 \times 10^8$ ... (7)

$Nu = 0.16(Gr \times Pr)^{0.333}$; $2 \times 10^8 < Gr \times Pr < 1 \times 10^{11}$ ... (8)

Heat transfer coefficient, $h = (Nu \times K) /$ ... (9)

Total Heat

The total amount of heat accumulated in the roller can be calculated by the following formula

$Q = Q_c + Q_r + Q_v$ ... (10)

$Q = \rho_{roll} \times V_{roll} \times C_{proll} \times (T_{ac} - T_2)$ ... (11)

Actual temperature of roll, $T_{ac} = (Q / (\rho_{roll} \times V_{roll} \times C_{proll})) + T_2$ ... (12)

Mass of water

The mass of water utilizing in the existing system for roll cooling.

$m_w = Q / (C_{pw} \times (T_{ac} - T_2))$ ... (13)

Spray width

The spray width can calculate by using this formula

$X = 2\ a \tan (\theta_n/2)$ ... (14)

Number of nozzles required

The Number of nozzles can be calculated by using the spray width and roll length. The number of nozzles by using the following formula

$N = L / X$ ... (15)

Where

L	Length of the roll
W	Width of the strip
r	Radius of roll
K	Thermal conductivity
T_1	Temperature of slab
T_2	Initial roll temperature
θ	Angle of contact
σ	Stefan's – Boltzmann constant
θ_n	Nozzle angle
Nu	Nusselt number
ρ	Density
s.f.	Shape factor
Pr	Prantle number
g	Acceleration due to gravity and
ε	Emissivity

VI Programming in Visual Basic

The coding has been done in Visual Basic to solve the mass of water coolant used to absorb the heat from the roll surface, so that the roll life will be increased and quality hot strips can be produced from the mill. The code written in Visual Basic is shown in flow chart (figure 4). The purpose of programming in Visual Basic are

- To solve the mathematical equations.
- To obtain the effective cooling rate required.
- To obtain the number of nozzles required.
- To obtain the spray width required.

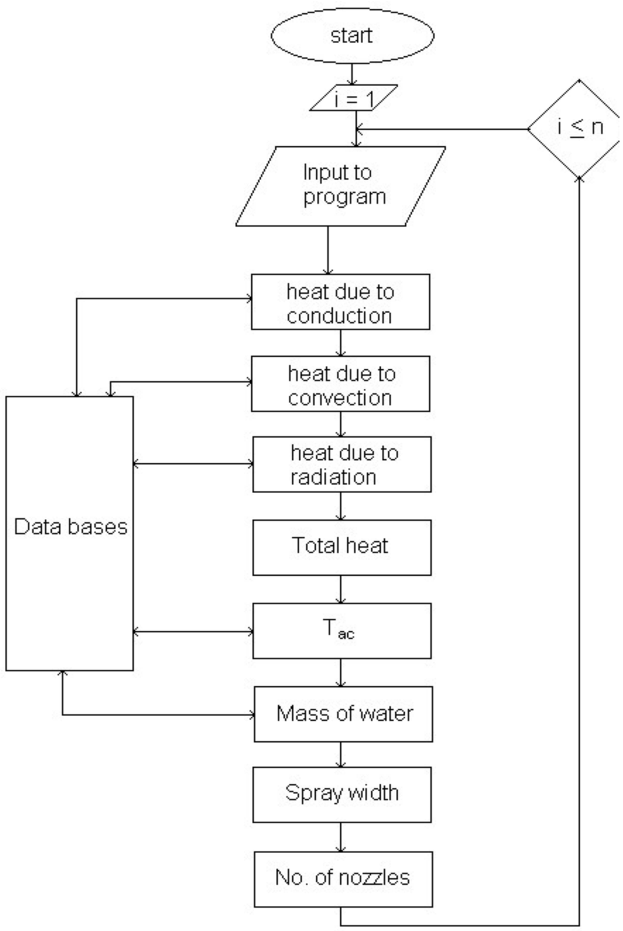

Figure 4: Flow chart for programming in Visual Basic

After writting the code the input form obtained in Visual Basic is as shown in the figure 5. In the input form the data should be entered.

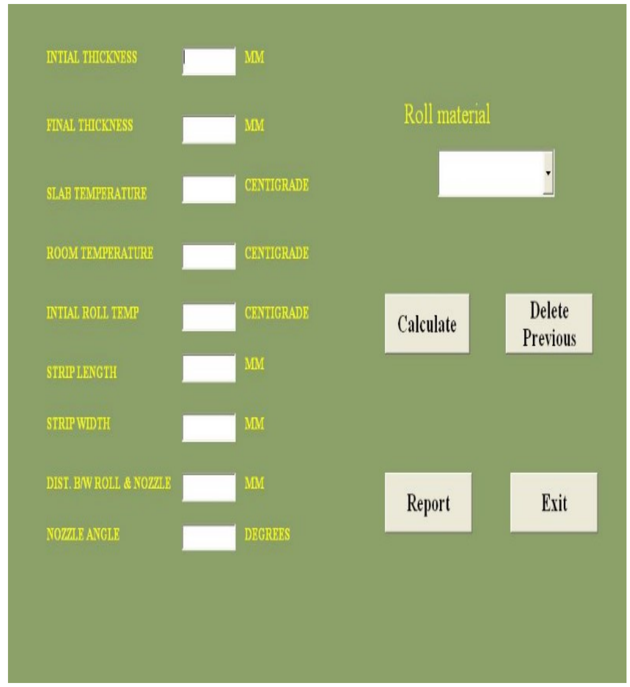

Figure 5:Input form in Visual Basic

VII Results and discussions

Thermal analysis of the existing system

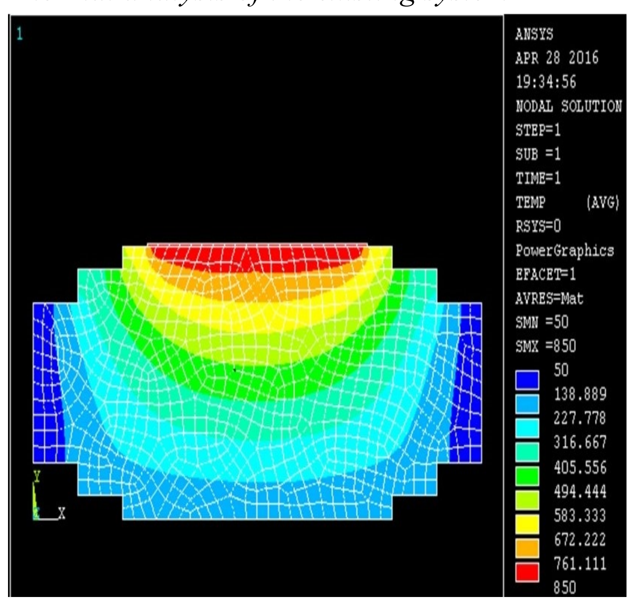

Figure 6: ANSYS result for existing system

In the above figure 6 shows the thermal deformation is due to the high temperature. Roll cooling system will attain high temperatures due to inefficient cooling in the

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system. The roll surface is free meshed and the type of element taken for analysis is plane 77. The temperature on the surface due to conduction, convection and radiation is at 850°C.The 2D contact analysis results described below. The ANSYS result of the existing system is as shows the effected area over the roll surface as in the above figure. The red colored region indicates the more affected area. The contact surface between roller and hot strip is the most affected region compared to other. In this region, there is a chance for deformation of roll material finally it will cause for formation of cracks on the roll surface. As the heat passes to other end surface of the roller the temperature will be decreased, and the effect of heat will be less. In the red zone, there is a chance to formation of cracks on roll surface. Dark blue region shows the room temperature (50⁰C). There is a chance of thermal deformation in red colored region.The maximum temperatures attained by the surface of roll due to contact with the hot strip. The end areas of the roll are at low temperatures because there is no contact surface with hot strip.

Output form in Visual Basic

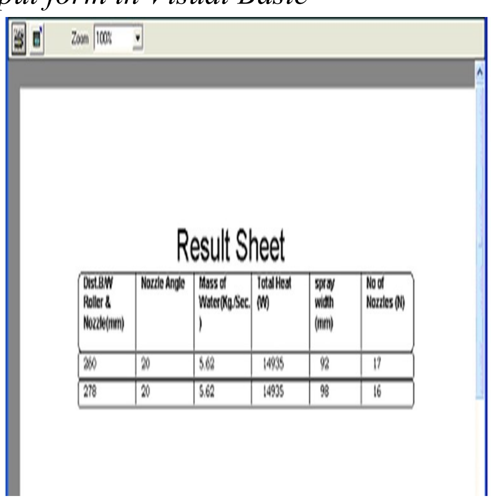

Figure 7:Output screen in Visual Basic

The results of the thermal calculations such as nozzle angle, mass of water coolant required for the effective cooling of roll system, spray width, number of nozzles required and the total heat on the roll surface are calculated by visual basic coding and tabulated as in the table 1. From these values a best value picked for optimal design of cooling system for rolls. The visual basic result form is shown in figure 7. Result sheet contains the decision parameters of the effective cooling system. Selecting a best value from the outputs of the program which is tabulated in table 1.

Table1: Results for different inputs

Distance between Roller & Nozzle (mm)	Nozzle Angle	Mass of Water (Kg./min)	Total Heat (W)	Spray width (mm)	No. of Nozzles
260	20	5.62	14935	92	17
262	20	5.62	14935	92	16
263	20	5.62	14935	93	16
265	20	5.62	14935	93	16
266	20	5.62	14935	94	16
267	20	5.62	14935	94	16
268	20	5.62	14935	95	16
270	20	5.62	14935	95	16
272	20	5.62	14935	96	16

275	20	5.62	14935	97	16
277	20	5.62	14935	98	16
278	**20**	**5.62**	**14935**	**98**	**16**
279	20	5.62	14935	98	15
280	20	5.62	14935	99	15
281	20	5.62	14935	99	15

$$\text{Efficiency} = \frac{\text{amount of heat absorbed by the water from the work roll surface}}{\text{amount of heat contained by the work roll surface}} \text{X } 100$$

VIII Comparison of results

In the present system, the actual temperature of roll surface is of 85^{0}C, but in the proposed system this temperature is reduced to 65^{0}C by increasing the no. of nozzles and decreasing the distance between the roller and nozzle. Proposed system suggesting to increase the coolant rate by increasing the nozzle numbers, for effective removal of heat from the system can be achieved by reducing the distance between the roll and nozzles.Comparison between the existing system and proposed system. The comparison table and comparison chart is shown in table 2 and figure 8.

Table2: Comparison of results

System	Temperature of roll (^{0}C)	No. of nozzles	Mass flow rate (kg/s)	Efficiency (%)
Present	85	14	4.8	40.85
Proposed	65	16	5.62	61.53

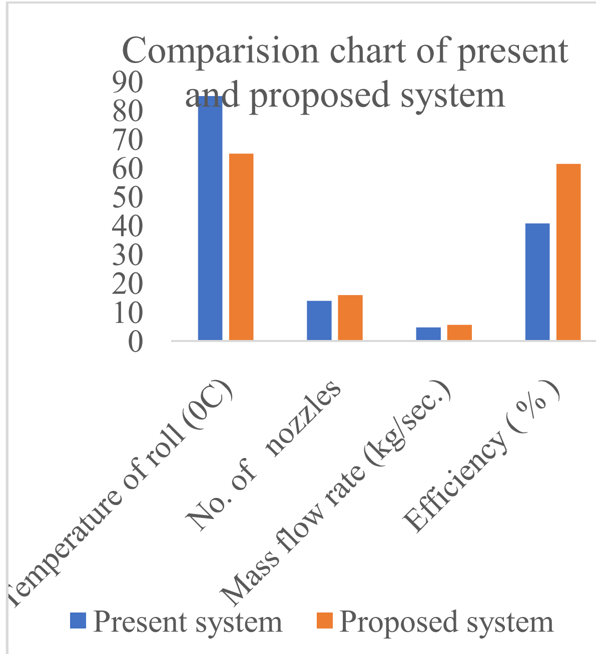

Figure 8: Comparison chart of present and proposed system

IX Conclusion

Results based on experiments with a different number of rows of nozzles showed how the cooling intensity could grow with an increasing in the number of nozzles. The tests with the specific nozzle length from the roll surface suggest more effective cooling for remote sprays. For bothe low and medium coolant pressures, this finding was confirmed. Numerical rolling calculations show high sensitivity of the roll crown frequency distribution along the roll distance. The same cooling, positioned at different roll positions, has been shown to have a completely different roll positions, has been shown to have a completely different effect on the thermal balance and roll crown. All the findings presented would support the conclusion that only industrial or laboratory studies or mathematical models could not be used to maximize cooling.

References

1. Carless P. (2000) 'Present and future hot strip mill finishing train work rolls' Ironmaking and steelmaking journal Vol.27 No.1 pp.7-10.
2. Graham Honeyman and John McCann (1999) 'Rolls 2000 +' Ironmaking and steelmaking journal vol.26 No.3 pp.151-163.
3. Raudensky M., Horsky J. and Pohanka M. (1999) 'Optimal Cooling of Rolls in Hot Rolling' proceedings of 1st International Conference on Modeling of Metal Rolling Processes, London, UK, pp. 660-667.
4. Schroeder K.H (1991) 'Roll cooling and lubrication' Ironmaking and steelmaking journal Vol.18 No.3 pp.11-13.