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Thermal Stress Analysis for Shrink fitting System used for Ceramics Conveying Rollers in The Process of Separation

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Abstract. Steel conveying rollers used in hot rolling mills must be exchanged very frequently at great cost because hot conveyed strips induce wear on the surface of roller in short periods. In this study, new roller structure is considered which has a ceramics sleeve connected with two short steel shafts at both ends by shrink fitting. Here, the ceramics sleeve may provide longer life and reduces the cost for the maintenance. However, sometimes the steel shaft has to be pulled out for exchange. Simply, heating outside surface and cooling inside surface of the shaft are necessary for separation. However, attention should be paid to the maximum thermal stress of the ceramics sleeve in the process of separation. In this paper, finite element method analysis is applied to the structure and thermal stress has been calculated with the varying dimensions of the structure. Also several effects on thermal stress have been investigated, such as the effect of shrink fitting ratio, outside diameter, the fitted length, thickness of shaft, materials an so on. Finally the most appropriate thermal conditions to reduce maximum stress and make separation easy have been discussed, which is very useful for designing of new rollers.

Introduction

Cast iron and steel conveying rollers used in hot rolling mills (see Fig.1) must be changed very frequently because conveyed strips with high temperature induces wear and deterioration on the roller surface in short periods. In this study, the new roller structure is considered [1]which has a ceramics sleeve and two short steel shafts connected by shrink fitting at both ends, as shown in Fig. 2 (b). The material of the sleeve is excellent ceramics which has heat resistance and abrasion resistance [2]. The exchanging cycle of roller can be extended in a large scale; additionally, the

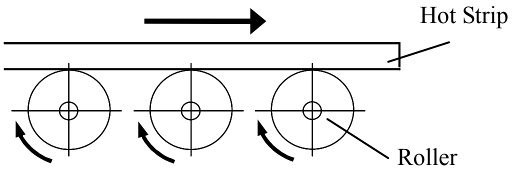


Fig.1 Layout of Conveying Rollers

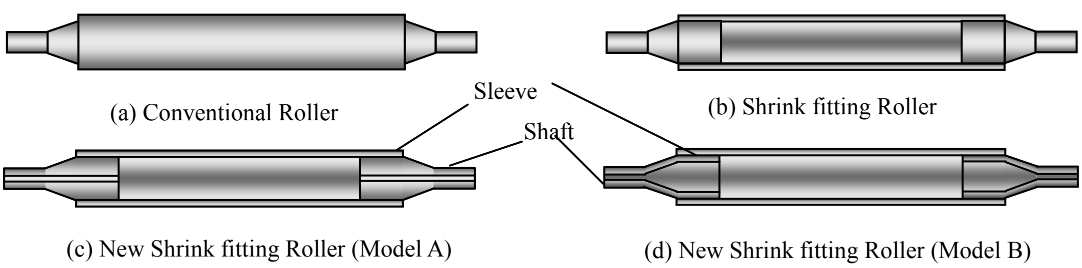
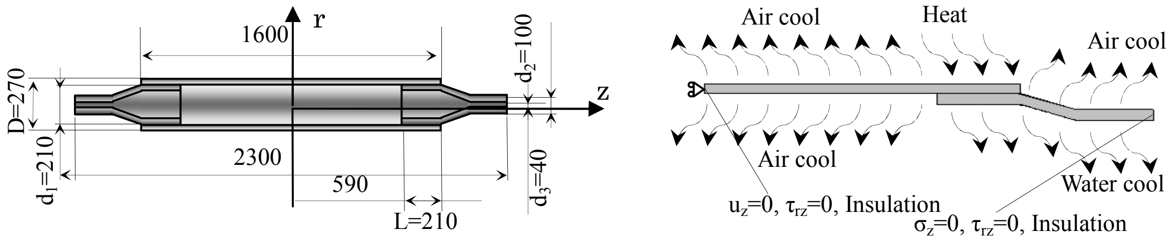


Fig.2 Roller Structure



(a) Dimensions (b) Boundary condition

Fig.3 Models considered (mm)

Table1 Material properties

	Ceramics H	Ceramics I	Steel (HV200)
Young's modulus [MPa]	300	294	210
Poisson's ratio	0.28	0.27	0.3
Tensile strength [MPa]	500	500	600
Mass density [kg/m^3]	3200	3260	7800
Thermal conductivity [W/m·K]	62.5(393K) 12.5(1273K)	17(393K) 3.4(1273K)	25
Thermal expansion coefficient [1/K]	3.0×10^{-6}	3.0×10^{-6}	1.45×10^{-5}
Specific heat [J/kg·K]	680	650	477
Emissivity	0.4	0.4	0.4

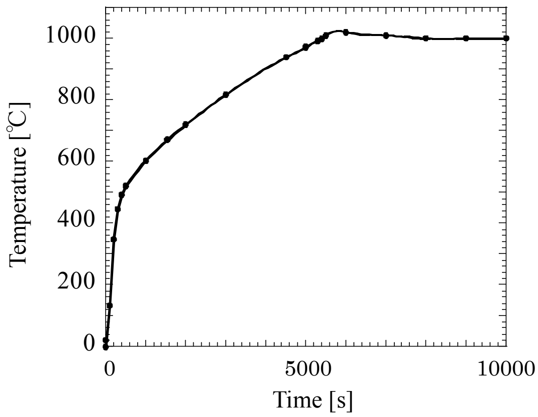


Fig.4 Atmosphere temperature

maintenance time and cost can be reduced. Moreover, the roller can be rotated easily and follow the speed of the transporting strips smoothly because of its light weight. As in the previous research [1], the effects of shrink fitting ratio and load distribution on the maximum stress have been discussed systematically. The steel shaft has to be exchanged frequently under corrosive ambient surroundings causing wear, fatigue and so on. It is therefore important to investigate the maximum stress of structure in the process of separation.

In this study, the structure of model B in Fig. 2(d) is mainly considered for stress analysis in the process of separation. The dimension of model B in detail is shown in Fig.3 (a). Combined with the effects of shrink fitting ratio, outside diameter, the fitted length, thickness of the shaft and material of the sleeve on separation time [3], we will discuss the effects of those factors on the maximum stress of the sleeve in the whole process of separation by the finite element method.

Analytical Conditions

Define the shrink fitting ratio as δ/d, where δ is the diameter difference with the diameter $d = 210mm$. The atmosphere temperature is assumed according to the heating temperature in the furnace experiment as shown in Fig. 4. Heating time was assumed as 10000s, reaching the highest temperature (1000℃) at about 6000s. As shown in Fig. 3(b), heating part is outside surface of the contact part of sleeve; water cooling part is inside surface of the shaft; air cooling part is sleeve's outside, inside, right end surface and shaft's outside, left end surface. The heating and water cooling is assumed as forced convection, while the air cooling is assumed as natural convection. In addition, axisymmetric models are used for analysis. The boundary condition at left end surface of sleeve is insulation with axis direction fixed (u_z=0, τ_{rz}=0), while at right end surface of shaft it is insulation with axis direction is fixed (σ_z=0, τ_{rz}=0). It is known that heat transmissions along the interface are mainly due to solid thermal conduction of real contact part and partly due to thermal

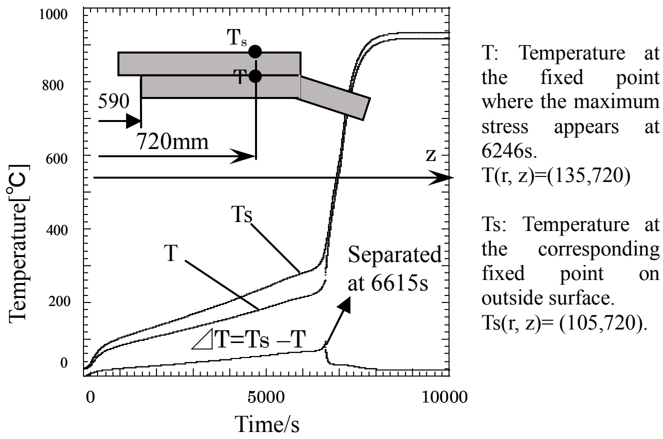


Fig.5 Temperature history in the whole process of separation

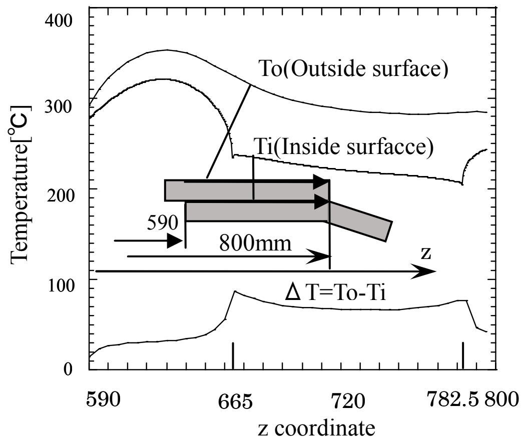


Fig.6 Temperature distribution along the interface when the maximum

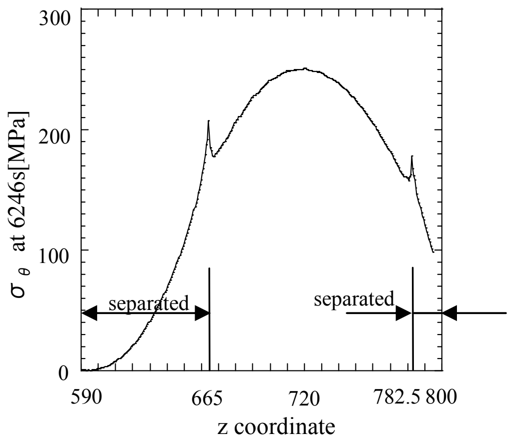


Fig.7 Stress distribution on the contact area when the maximum stress exists

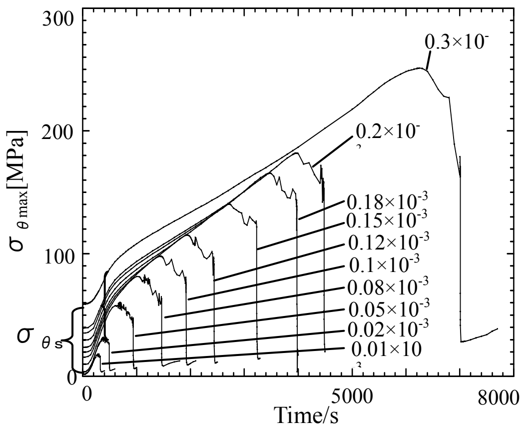


Fig.8 Maximum stress vs. time

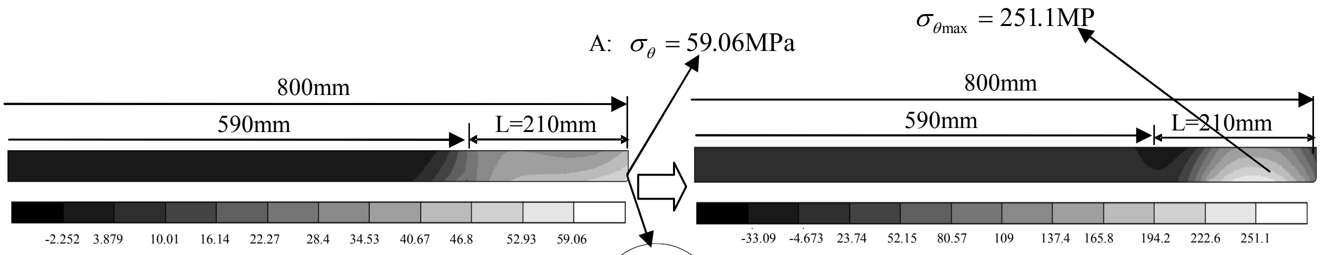
conduction through fluid that lies between space in contact part [4]. However, in this analysis solid thermal conduction is predominant and contact heat transfer coefficient is assumed as $1.0\times10^9 W/m^2 \cdot K$.

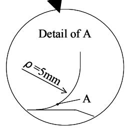
Table 1 shows the material properties of the roller. The material of shaft is always steel while for sleeve, two kinds of ceramics are considered, ceramics H or ceramics I.

Results and Discussion

Stress Analysis with Separation Conditions

Figure 5 shows the temperature T at the position where the maximum stress appears at 6246s. The temperature at the corresponding position on the outside surface of the sleeve is also shown in the whole process of separation for $\delta / d = 0.3\times10^{-3}$. It should be noted that the sleeve and shaft are separated at 6615s. Before separation at 6615s, the temperature difference increases gradually while it becomes nearly zero after separation, which means the temperatures of inside and outside of the sleeve are almost same after separation. Figure 6 shows the temperature distribution along the interface and the outside surface of the sleeve when the maximum stress appears at 6246s, while the temperature distribution contour is shown in Fig. 10. As shown in Fig. 6, from z=590mm (left end) to 665mm and z=782.5mm to 795mm (right end) along the interface, the sleeve has been separated from the shaft. Therefore, the temperature from z=665mm to z=782.5mm is lower than the separated parts. Figure 7 shows the stress distribution along the interface when the maximum





(a) σ_θ due to shrink fitting($\sigma_{\theta s}$) (b) σ_θ by applying thermal loads after shrink fitting

Fig.9 Stress distribution of sleeve for $\delta / d = 0.3\times10^{-3}$

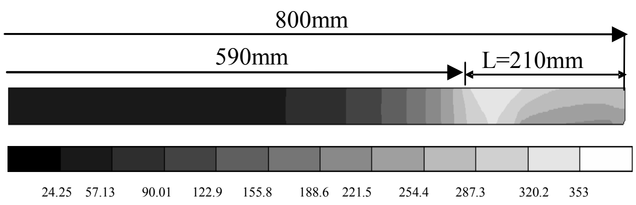


Fig.10 Temperature distribution of sleeve when maximum stress exists at 6246s for $\delta / d = 0.3\times10^{-3}$

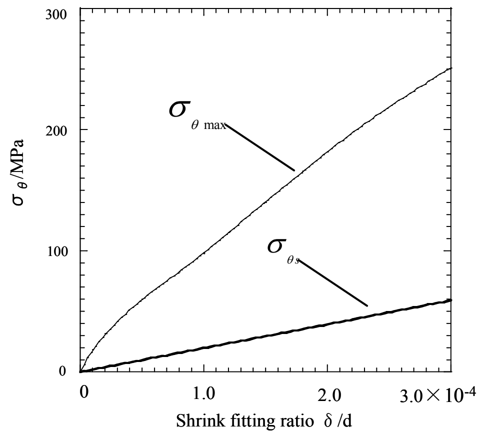


Fig.11 Effect of shrink fitting ratio on $\sigma_{\theta s}$ and $\sigma_{\theta\max}$

stress $\sigma_{\theta\max} = 251.1$MPa appears at 6246s. Maximum stresses vs. time relation have been indicated in Fig. 8 for different shrink fitting ratio δ/d. Here $\sigma_{\theta\max}$ at t=0 is the shrink fitting stress $\sigma_{\theta s}$. Figure 9(a) shows the stress $\sigma_{\theta s}$ due to shrink fitting and Fig. 9(b) shows maximum stress $\sigma_{\theta\max}$ due to thermal loads after shrink fitting. As shown in Fig. 9(a), the maximum tensile stress is 59.06MPa for shrink fitting when $\delta/d = 0.3\times10^{-3}$. It becomes 251.1MPa by applying thermal loads after shrink fitting. Figure 11 shows effects of shrink fitting ratio δ/d on the shrink fitting $\sigma_{\theta s}$ and maximum stress $\sigma_{\theta\max}$ when thermal loads are applied after shrink fitting.

Conclusions

Conveyed strips with high temperature induce wear and deterioration on the roller surface in short periods and maintenance cost increases by exchange the rollers. In this study, a new roller structure was considered. Then, the effects of different aspects of factors on thermal stress were investigated. The most appropriate thermal conditions to reduce maximum stress can be discussed from other results in this study.

References

[1] Masakazu Tsuyunaru, Nao-Aki NODA, Hendra., and Yasushi Takasei, “Maximum Stress for Shrink Fitting System Used for Ceramics Conveying Rollers”, Transactions of the Japan Society of Mechanical Engineering, Vol.74, No.743 (2008), pp.919-925 (in Japanese).

[2] Iwata, T. and Mori, H., ”Material Choice for Hot Run Table Roller”, Plant Engineer, Vol.15, No.6 (1983), pp.55-59 (in Japanese).

[3] Wenbin Li, Hiromasa Sakai, Yasushi Takasei, Nao-Aki NODA, “Analysis of Separation Conditions for Shrink Fitting System Used for Ceramics Sleeve”, Proceedings of Japan Society of Mechanical Engineering, No.108-1(2010), pp195-196.

[4] Torii, K., “Heat Transfer Across the Solid Interface Governed by its Microscopic Surface-Structure –Interface between Macro-and Micro-Mechanics”, Journal of the Japan Society of Mechanical Engineers, Vol.96, No.892 (1993), pp.198-203 (in Japanese) .

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