Fatigue Life Evaluation of Spindle of Rolling Mill using Computational Numerical Analysis

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1. Introduction

A rolling mill is a machine that produces a coil by rolling material using a roller, and the spindle of the rolling mill device serves to transmit the power to the rollers through the periodic rotation of the motor. These spindles comprise universal joints, shafts, and bearings to deliver power to the rollers. The spindle of the rolling mill is always exposed to the environment and is subjected to fatigue load owing to the rotation moment caused by the periodic rotation. Thus, there is a possibility of breakage occurring. It is vital to prevent breakage by predicting the fatigue life of the spindle in a dynamically operating environment. The fatigue life prediction method using numerical analysis is the latest evaluation technology to predict the fatigue life using the stress data obtained from the structural analysis to reduce the evaluation time and cost [1-2]. Therefore, in this study, dynamic stress analysis was performed considering the actual rotating environment conditions using ADINA, a structural analysis program. Based on the results of the stress analysis, we predicted the fatigue life considering the dynamically operating environment using winLIFE, a fatigue life analysis program. Fig. 1 illustrates the work flow diagram of the dynamic stress analysis and fatigue life analysis of the rolling mill spindle performed in this study. The analysis performed in this study can be classified into dynamic structural analysis and fatigue life analysis.

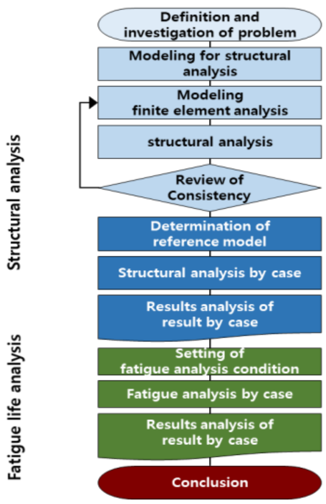


Fig.1 Flow chart of this study

2. Dynamic structural analysis with ADINA

In this study, ADINA, a commercial program, was used to analyze the dynamic structure of a spindle. This program is used for various multi-physics analyses, such as nonlinear structural analyses, heat-structure ductile analyses, and fluid structure interaction analyses [3-4]. Fig. 2 depicts a three-dimensional model designed based on the shape of the actual spindle and comprises a universal joint, shaft, and bearing. As shown in Fig. 2 and Table 1, the bearing constraint, rotational dis-

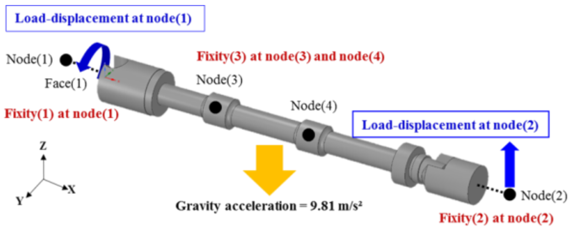


Fig.2 Model and boundary condition

Table 1 Boundary condition of analysis

Condition	Contents	Setting
Constraint	-Motor side -Roller side -Bearing side	* Node(1) X,Y,Z(M), Y,Z(R) * Node(2) Y(M), Y,Z(R) * Node(3), (4) Nothing(M, R)
Rotational displacement	Rotation velocity	* Node(1) : Motor rotation
Moving displacement	Coil thickness	* Node(2) : Roller moving
Gravitational acceleration	Coil thickness	9.81 m/s^2

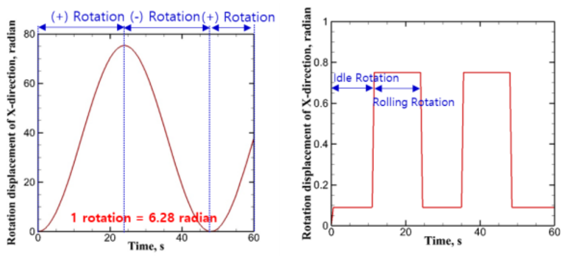


Fig.3 Condition of rotational displacement

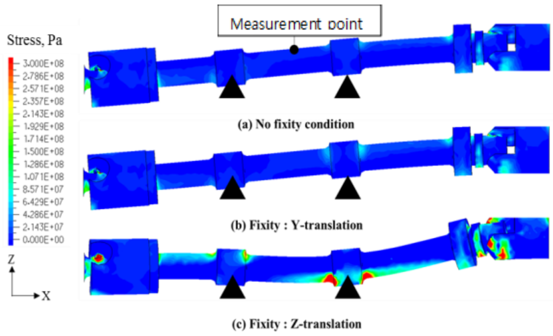
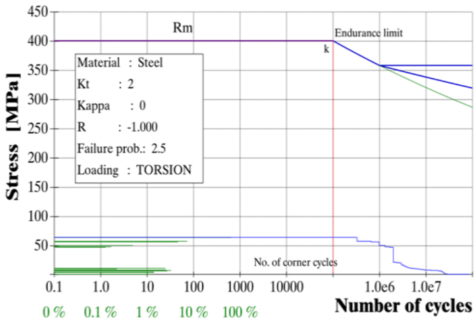


Fig.4 Result of stress distribution(86.58sec)

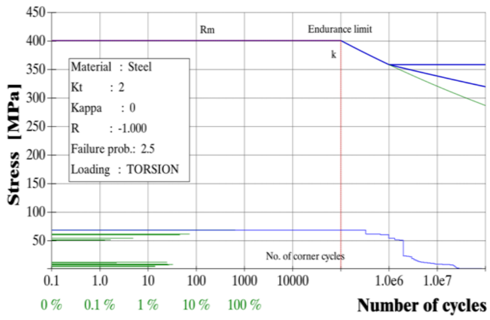
placement condition, moving displacement cond -ition, and gravitational acceleration condition are set as boundary conditions. The following cases are classified according to the bearing constraint condition. Case (1) has no constraint on the bearings, whereas cases (2) and (3) set constraints on the Y and Z-direction movement, respectively. In the case of the spindle model, the torsional moment caused by the rotation significantly influences the structure. Therefore, the stress distribution in the circumferential direction was analyzed. Fig. 4 illustrates the stress distribution according to the bearing constraint condition of 86.58 s.

3. Fatigue life analysis with winLIFE

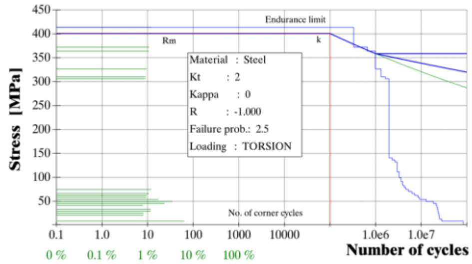
In this study, we used the commercial program, winLIFE, to predict the fatigue life of the spindle. This program was developed in Germany and is used for the evaluation of the fatigue life of single shafts, multi-shafts, and gear bearings. It generates the S-N and E-N curves using its vast database of physical properties. The mechanical properties (T.S



(a) S-N curve of case (1)



(b) S-N curve of case (2)



(c) S-N curve of case (3)

Fig.5 Result of fatigue life analysis

860 MPa) of the spindle are applied in the analysis. The results of the stress distribution according to the bearing constraint of 86.58 s, as depicted in Fig. 4, derived from the dynamic structural analysis results were used as the applied values of the stress data.

4. Conclusion

As a result of the fatigue life prediction, the spindle was predicted to be available for 1.0343e + 15 years without bearing constraints. Fig. 5(a) illustrates the S-N diagram and fatigue load. The fatigue load was within the fatigue life limit of the S-N line. In case (2), the fatigue life of the spindle was predicted to be available for 2.5461e + 14 years, as depicted in Fig. 5(b). As a result of the fatigue life prediction in Fig. 5(c), the fatigue load was higher than the fatigue life limit of the S-N curve in case (3).

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