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Fundamental Behavior Analysis of SCM440 Steel on Friction and Wear

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SCM440강에 대한 마찰 마멸의 기본적 거동해석

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ABSTRACT

Due to the increased use of power caused by industrial development, the importance of improving wear and friction in the contact region has emerged. Except for some parts, such as brakes or clutches and friction, seals and precision mechanical parts (e.g., pistons, bearings, valves, and cams) are important engine components that require low friction characteristics. In this study, the experimental method used to determine the friction characteristics was based on the type of rpm with the pin-on-disc test device, the element analysis program ANSYS was used to analyze the surfaces of the two metals rubbing together, and physical formation FEM models were used to study the properties and wear. The friction coefficient of variation was unsafe, but at the start of wear, it converged to a stable friction coefficient that increased after a certain slip away.

Key Words : Friction Stress(마찰힘), Wear(마멸), Numerical Model(수치모형), Archard`s Model(아차드 모형)

1. Introduction

Due to the use of power by industrial development, the importance of wear and friction in the contact region has emerged as a relative improvement. Such as brake or clutch and friction, except for some parts, seals and precision mechanical parts such as pistons, bearings, valves, and cams is an important engine component and require low friction characteristics. All moving objects are interconnected accompanied by friction, and a large amount of energy required has been reduced due to friction. If the energy loss due to friction can be reduced by minimizing friction in the economic field, the benefits are enormous. In addition, parts for machines that are currently used in aerospace, artificial organs, and in extreme circumstances such as the semiconductor industry to expand in areas requiring a long life.

This research has and continues to remain technique of attracting attention for controlling the frictional force. Pin on disc test method used in the

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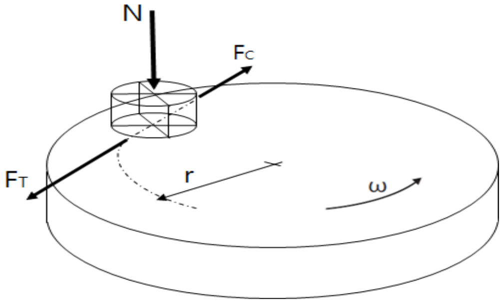


Fig. 1 Schematic of forces acting in a pin on disc test

present experiment that has been widely used to study the frictional characteristic through the sliding contact between two metals surface, and have been used to evaluate the characteristics of friction and wear. Common mechanism for friction curves used in this study is the Stribeck curve.

In this study, the experimental method used to determine the friction characteristics based on the type of rpm with the Pin on disc test device, element analysis program ANSYS is used to analyze the surface of the two metals rub together, through the physical formation FEM models are used to study the properties and wear.[2-5]

$$F_T = F_{app} \tag{1}$$

$$F_{Net} = F_{tf} \tag{2}$$

$$\mu = \frac{F_{tf}}{W} \tag{3}$$

Fig.1 shows a schematic view of the direction of force Pin on disc tester. Load over the pin (N) is applied and the disc is rotated at a constant angular velocity (ω). Due to the rotation of the load at a constant angular velocity in the pin friction there arose.[1]

The force exerted on the surface spaced apart by r from the center of the disk, as opposed to the friction force showed relatively small compared with the force and size as shown in equation (3). Two contact surfaces due to the resultant force (net force) will be represented tangential load (tangential load), as shown in equation (4) can be obtained as shown in equation (5) the coefficient of friction.

1.1 Archard equation

Archard wear and slip a simple model equations used to describe the wear and tear, and are based on the theory of contact materials science. This study is expected to be rubbed with Archard model is applied to the surface of the disc is expressed as Equation 4.

$$Q = K\frac{WL}{H} \tag{4}$$

Q $[m^3]$ is the volume of material wear, L $[m]$ is the distance friction (sliding distance), H [Pa] is the material hardness, W [N] is the vertical load of the material, K is the wear factor (coefficient). Wear coefficients derived from the experimental method Pin and Disc through Archard wear equation in this study, and to investigate the relationship between rpm. To predict the depth of the wear of friction on the surface of the disc used ANSYS W/B.

1.2 Non-disposable(Specific Wear Rate)

Wear rate is the ratio to compare the wear rate of materials and the shear distance value with the vertical load on the same amount of wear to the equation 5.

$$\dot{w}_s = \frac{\Delta m}{\Delta t}\frac{1}{v\rho F_N} \tag{5}$$

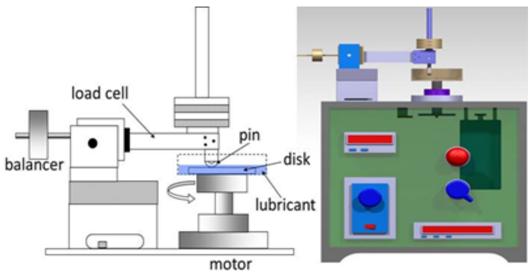
$[m]$ is the mass of material wear, $[v(m/s)]$ is the average speed of the disc wear track line, $[\rho\ (g/mm^3)]$ is the density of materials, $[F_N]$ is applied perpendicular to the disk drag, $[t]$ is the measurement time. Wear rate is the ratio of the dimensions $[mm^3/N/m]$, wear rate of the non-physical tool shows the volume of material losses for all kinds of energy.

2. Experiment Details

2.1 Schematic of pin on disc machine

When the two surfaces are in contact there arose the tangential load by the normal stress. Relationship Forces between two components is generally known as a frictional force, and is expressed in terms of stress. Fig. 2 Pin on disc test apparatus after amplification using the indicator of voltage signal from tension and compression load cell is converted into the analog / digital converter for input to the computer, and was calculated by the coefficient of friction of the program.

This experiment using SCM440 specimens, the diameter of the specimen is Φ60 and has a thickness



(a) Detail part structure (b) Schematic of pin on disc machine

Fig. 2 Pin on disk type friction test machine

Table 1 Chemical composition and mechanical properties of specimens

Chemical composition		Mechanical properties	
C	0.38~0.43	Tensile stress (kg_f/mm^2)	75
Si	0.15~0.35		
Mn	0.60~0.90	Yield strength (kg_f/mm^2)	90
P	Below 0.030		
S	Below 0.030	Elongation	14%
Cu	Below 0.025	Hardness (HB)	255~321
Ni	0.02~5		
Cr	0.90~1.20	Density (g/cm^3)	7.85
Mo	0.15~0.30		

Table 2 Experiment test condition

Parameters	Condition
Contact type	Pin on disc
Disc material	SCM440
Pin material	SCM440
Diameter of disc / thickness	60mm / 5t
Diameter of pin / thickness	4mm / 1t
Normal load range [N]	20N
Rotational speed [rpm]	143, 105, 67, 29
Lubricant	non-lubricant
Temperature	Room temperature

5t, Pin has a thickness 5t with Φ4. Table 1 shows the ratio of chemical components of physical characteristics of the sample. Experimental tests were in non-lubricating state Gave a load of 20N 143rpm, 105rpm, 67rpm, and 29rpm, every five minutes in the "room temperature" was measured the friction coefficient for treatments call now using the precision electronic scale to measure the amount of abrasion of the test piece. Table 2 shows the present experimental conditions.

2.2 Numerical model

Pin on disc test was used for simulation analysis program "ANSYS" to generate analytical models, models grid generation, interpretation definition sets, target analyzes were performed using a four-step analysis. The analysis model is generated using ANSYS / CAE, ANSYS / Structural Transient solver is used to analyze the structure depends on the time performed on the Pin on disc test to disk element analysis (Finite Method -Element).

2.2.1 Interaction module

Table 3, 4 shows the contact between Pin and

Disc. Contact characteristics to represent the surface friction between the bottom and the top surfaces of the Pin Disk was friction "Behavior-Symmetric" determined to both contact surface to prevent infiltration. Augmented Lagrange method commonly used for nonlinear contact analysis by including the value of friction coefficient 2.3592×10^{-2} were obtained from the load and the experimental values 143rpm Pin disc test of political 20N.

Fig. 3 is designated in a Cylindrical Support thickness portion to prevent the detachment of the

Table 3 Statistics of Node and Elements

Statistics	Part Name		Method
	Disc	Pin	
Node	29,261	234	Tetrahedrons
Elements	16,819	100	

Table 4 Interaction properties

Interaction	Pin surface /disc surface
Contact property	Frictional
Behavior	Symmetric
Formulation	Augmented Lagrange
Friction coefficient	2.23592×10^{-2}

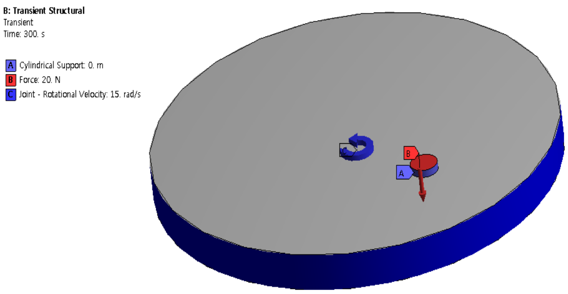


Fig. 3 Simulation of pin on disc test in the ANSYS

Table 5 Boundary conditions of load module

Joint		Type	Magnitude
Revolute - Ground to Disk		Rotation Velocity	15rad/s
Type	**X Component**	**Y Component**	**Z Component**
Force	0N	0N	-20N

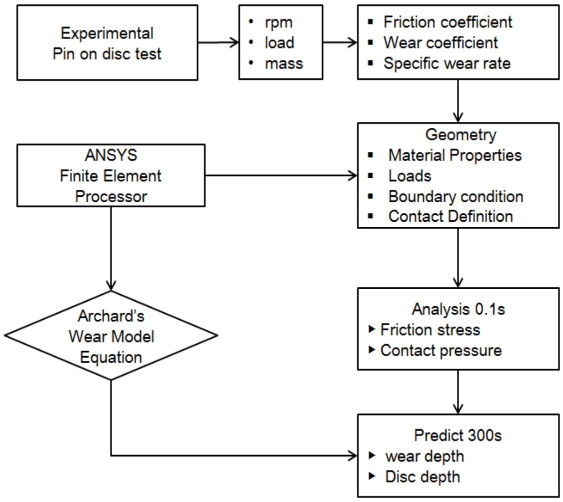


Fig. 4 Flowchart for analysis of pin on disc

vertical direction of the disc by simulation showing the boundary conditions of the analysis. Table 6 is a boundary that is the angular speed of 143rpm 15rad / s at Pin Disc has to exert a force on a load of 20N for analysis illustrates the boundary conditions used in the analysis in the -Z direction on the upper surface of the pin to the rotation of the friction conditions were entered Fig. 4 shows the flow diagram of the entire analysis using pin on disc test with ANSYS.

3. Result and Discussion

3.1 Results

This experiment shows the results of four type's rpm variation are used with 20N load on Pin in the room with room temperature. Fig. 5 shows the Pin on disk test results on a graph of friction coefficient and time trial, 105rpm showed the greatest value, which is 0.0249480 and 29rpm shows the smallest value that is 0.0193481. Changes in friction coefficient up to steady state on 143rpm demonstrated the value 0.0235921 and on 67 rpm sliding distance of 0.0217166 indicates that stability is achieved after increasing the coefficient of friction on a certain amount.

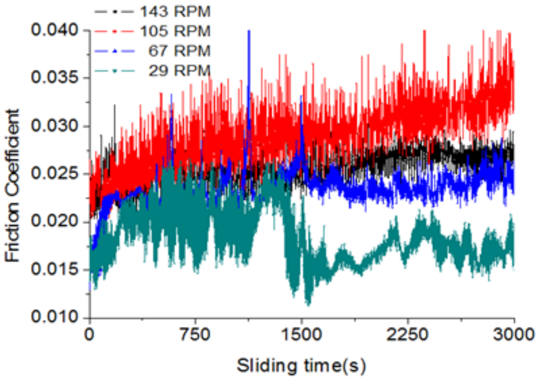


Fig. 5 Friction coefficient for the rpm(4type)

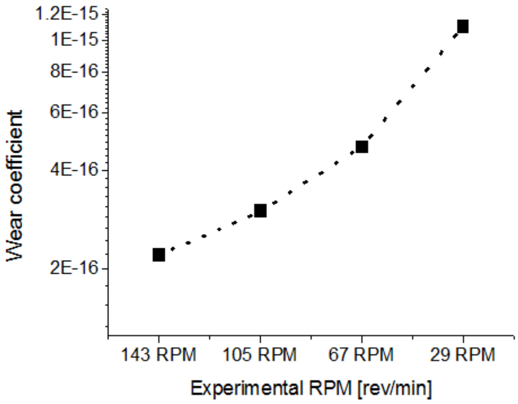


Fig. 6 Friction coefficient for the rpm

Table 6 Average values of friction coefficient obtained from experimental tests and wear coefficient calculated from experimental mass loss results

Elements	rpm[rev/min]			
	143	105	67	29
Friction coefficient	0.0235921	0.0249480	0.0217166	0.0193481
Wear coefficent	2.2×10^{-16}	3×10^{-16}	4.71×10^{-16}	1.1×10^{-15}

Fig. 6 shows a graph of four types rpm coefficient used in conjunction Archard equation to describe the wear and friction. 143 rpm with a value of 2.2×10^{-15}(non-dimensional) shows the value of the lowest wear factor. At 105rpm shows the value 3×10^{-16}, and to 67rpm show the value

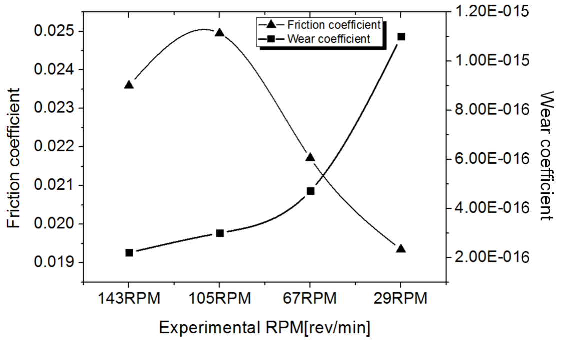


Fig. 7 Comparison between friction coefficient and wear coefficient during pin sliding over disc under 20N load

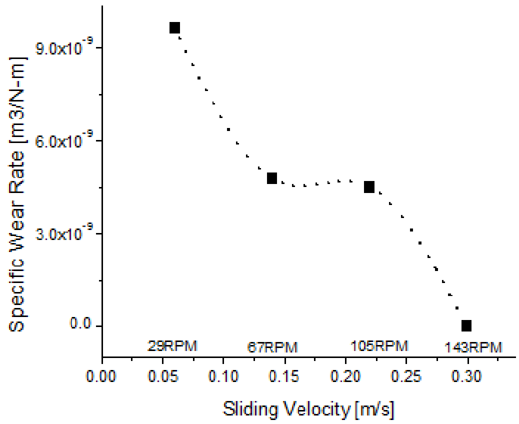


Fig. 8 Specific wear rate with sliding velocity

4.71×10^{-16}, 29rpm indicate value of 1.1×10^{-15}. At 143~67rpm showed a tendency to increase the coefficient of the substance constant, sudden increase shown in the use of 67~29rpm, in this experiment rpm is reduced to greater wear coefficient. Table 6 is a table showing the coefficient of friction and wear coefficient by comparing obtained through Pin on disc test and Fig. 7 shows a graph to see the remodeling of two results.

Case the coefficient is a friction coefficient of about 0.0013 rising from 143~105rpm and 105rpm after the friction coefficient was exhibited a tendency to continue to decrease to 105~29rpm was reduced to about 0.0056. Case the wear coefficient showed a difference of approximately 8×10^{-17} at 143~105rpm The remodeling was observed linear increase indicates that, at 105~67rpm showed a difference of 1.71×10^{-16} showed a nonlinear increase in remodeling. In addition, 67~29rpm was a relatively large increase of 6.39×10^{-16}. The coefficient of friction and wear coefficient 29~105rpm was inversely proportional the, 105~143rpm The proportional.

Fig. 8 is a graph showing a result of a Specific wear rate according to the slip speed. In the case of normal temperatures in the low speed of 29rpm Specific wear rate appears relatively large remained almost constant at 67~105rpm and then decreases after 105rpm. As shown in the Specific Wear Rate that results had a tendency to decrease with increasing ratio of the rpm.

3.2 Numerical model results

Fig. 9 represents about the shear stress on the contact area between pin and disc when 20N of load was given. The edge of disc was performing that 43.785 Pa of frictional stress at 143 of angular speed.This point receives the largest frictional stress caused by angular motion between pin and disc and another point around the center receives smaller stress. Based on this condition it can be concluded that the point is a potentially high in worn caused by abrasion from frictional surface contact. Fig. 10 shows the

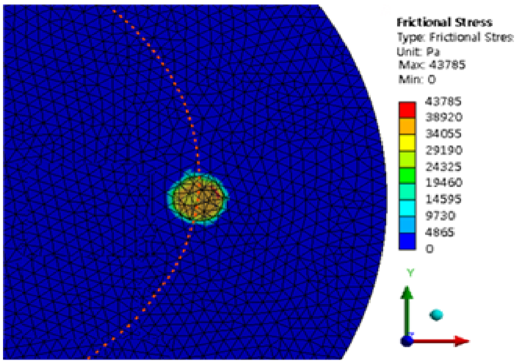


Fig. 9 Friction stress on the disc surface during sliding with 20N normal load

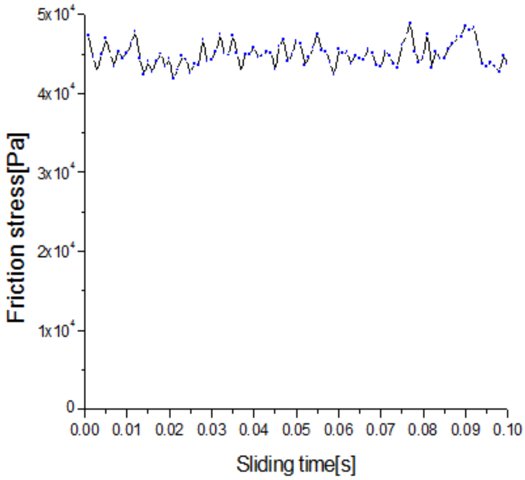


Fig. 10 Friction stress variation on disc surface

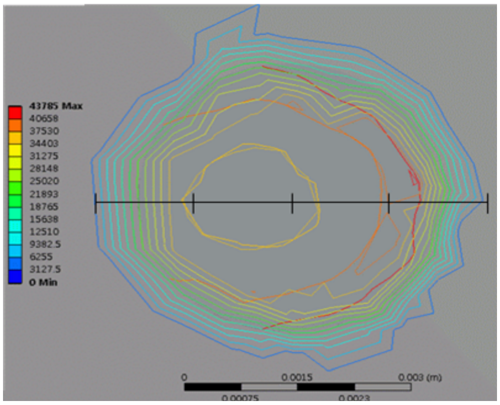


Fig. 11 Friction stress contour line on the disc surface

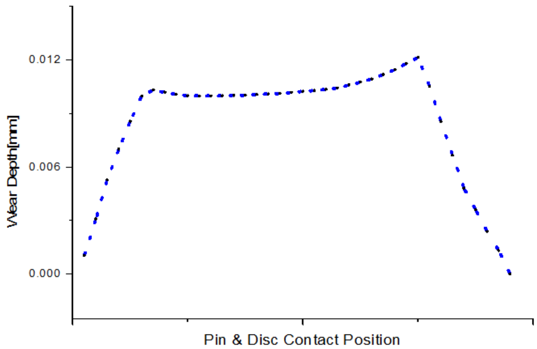


Fig. 12 Wear depth of 300seconds during pin sliding over disc under 20N load

change of friction stress in the contact area with the Pin and Disc. We knows that irregular change of friction stress and average value is 44.96kPa. Fig. 11 shows the contour lines of friction stress during the rotation about 0.1second. In order to predict the amount of wear during 300 seconds, the center of the contour lines divided 20parts. Frictional stress was used for prediction calculation wear depth using Archard's wear model.

Fig. 12 shows that During the 300 seconds the expected wear depth using Archard’s wear model when Pin on disc experiment. and it will become of 0.010~0.012mm in the center of the contact portion of the Pin and Disc.

4. Conclusion

Due to the use of power by industrial development, the importance of wear and friction in the contact region has emerged as a relative improvement. in this study, we investigated using an analytical method using the friction and wear characteristics of the experimental method and the ANSYS through the friction experiments in dry friction conditions of the Pin and Disc. The conclusion is obtained from the experimental and analytical results are as follows.

1. The friction coefficient of variation unsafe, but at the start of wear converge to a stable friction coefficient increases after a certain slip away. The coefficient of friction was hardest at 105rpm and reduced to 143, 67, 29rpm order.
2. Amount of wear and the wear coefficient corresponding to the distance of the Disc is showed the maximum value at 29rpm according to the increase of the rpm value exhibited a tendency to decrease. The coefficient of friction and wear factor is proportional to the 143~105rpm was the 105~29rpm was a tendency that is inversely proportional. In general, the wear is proportional to the friction coefficient, but there is also a case where the friction coefficient is large even if the wear is suppressed by the friction.
3. The Specific Wear Rate is showed a tendency to decrease as the sliding speed increases.
4. The farther from the center of rotation on the contacts of the Pin and Disc, the contact pressure and friction stress was relatively large. Wear in the center of the contact area on the Pin and Disc was relatively large. In addition, it was found that more wear farther from the center of rotation.

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