Decrease of reaction force of metal gaskets just after initial tightening

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Abstract

The decrease of reaction force of some metal gaskets inserted into the test flange at room temperature, 120°C(real cask temperature) and 200°C(accelerated condition) are measured. The reaction forces of metal gaskets in the room temperature have been almost not changed. The reaction force of 120°C and 200°C metal gaskets has decreased according to the temperature increase. After the temperature became stable, the decrease of the reaction force gradually proceeded, this decrease have been as same as previous studies.
The bolts of transport and storage casks are usually tightened just after the loading of spent fuels, and then the temperature of metal gaskets at that time is almost the room temperature. The reaction forces of the metal gasket tightened at this condition would be decreased after the temperature increase due to the decay heat of spent fuels. It is confirmed that the loosening of the bolts might be happened if the tightening torque of bolts is not appropriate. It is easy to evaluate that the reaction forces of the metal gasket in storage condition according to Larson-Miller parameter or relaxation of the gasket material, but the decrease of the reaction forces of the metal gasket just after the loading is not able to evaluate by these method. It is necessary to evaluate the reaction forces according to plastic deformation property of the metal gaskets so as to fasten the gaskets safety.

1. Introduction

Recently, the demands of transport and storage casks of spent fuels have been increasing worldwide. As higher reliance of containment function is required against the seal of these casks, metal gaskets are usually used for this purpose. The temperature of metal gaskets initially tightened to the flange of these casks is not so high, almost equivalent to the ambient temperature, but it increase after the tightening due to the decay heat of spent fuels. Then the property of metal gasket may change as temperature increase. This change may cause the decrease of reaction force against the tightening load of the bolts to these gaskets, and results in loosening of bolts. And after the temperature of metal gaskets reached to stable, the storage casks are usually applied for in-service for several years and the metal gaskets expose to high temperature for these period. This condition causes the relaxation of components of metal gasket.

Reaction force measurements for some metal gaskets have been performed. The data of the decrease of reaction force caused by the temperature increasing just after tightening the bolts and the reaction force variation after that have been obtained. The appropriate initial tightening techniques for metal gaskets and the evaluation method of the degradation of metal gaskets during the long storage period are studied here.

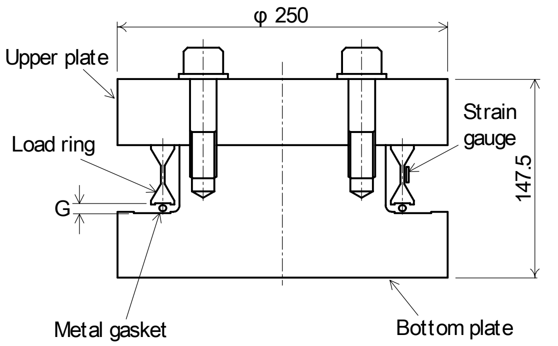
2. Experiment

2.1 Method of experiment

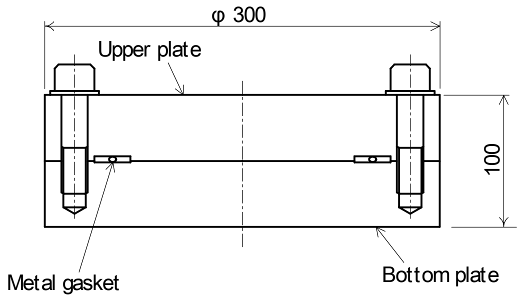
Some studies had already performed to evaluate the decrease of reaction force of metal gaskets. [1] [2]

These studies are enough to evaluate the long-term sealability of metal gaskets for spent fuel storage cask. But these are not enough data of initial decrease of reaction force of metal gasket caused by temperature increase. It is important for us to evaluate not only the decrease of reaction force caused by gasket relaxation in the long term storage but also the decrease of reaction force caused by gasket plastic deformation caused by the gasket material strength change depended on the gasket temperature. Plastic deformation is appeared during the temperature increase of metal gasket just after the tightening of cask lid bolts at ambient temperature. It is necessary to measure the reaction force, so we have examined using the test equipment as shown in Fig.1.

Test equipment “A” is the stress relief test flange and it is used for measuring the change of reaction force of metal gasket continuously. The load ring is installed between upper plate and bottom plate. Metal gasket is inserted under the load ring. The gap dimension “G” between the load ring and bottom plate after tightening the bolts is equivalent to gasket seal structure of storage cask.



A. Stress Relief Test Flange



B. Perfect Tighten Test Flange

Fig.1 Test Equipment

Test equipment “B” is the perfect tighten test flange and its structure of gasket groove is equivalent to the gasket seal structure of storage cask. It used to verify the result of test equipment “A”.

The test equipments are inserted in the electrical furnace after tightening the bolts. The stress of the load ring of test equipment “A” is started to measure after the tightening the bolts at ambient temperature. The reaction force of the gasket of the test equipment “B” is measured by the press load test machine after taking out from the electrical furnace as shown in Fig.2. The overview of the experiment is shown in Fig.3.

The gaskets used to the experiment are shown in Fig.4.

The condition of experiment is shown in Table 1.

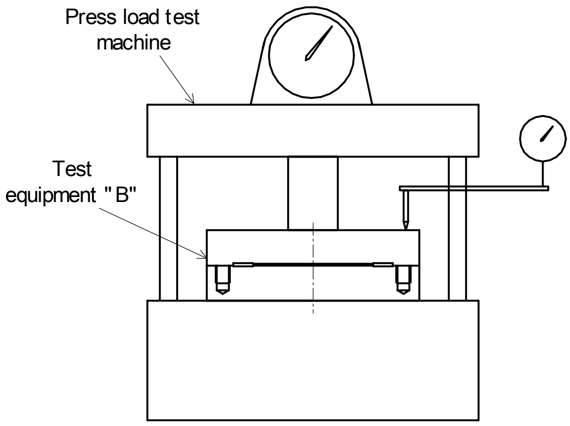


Fig.2 Measurement of the reaction force of test equipment “B”

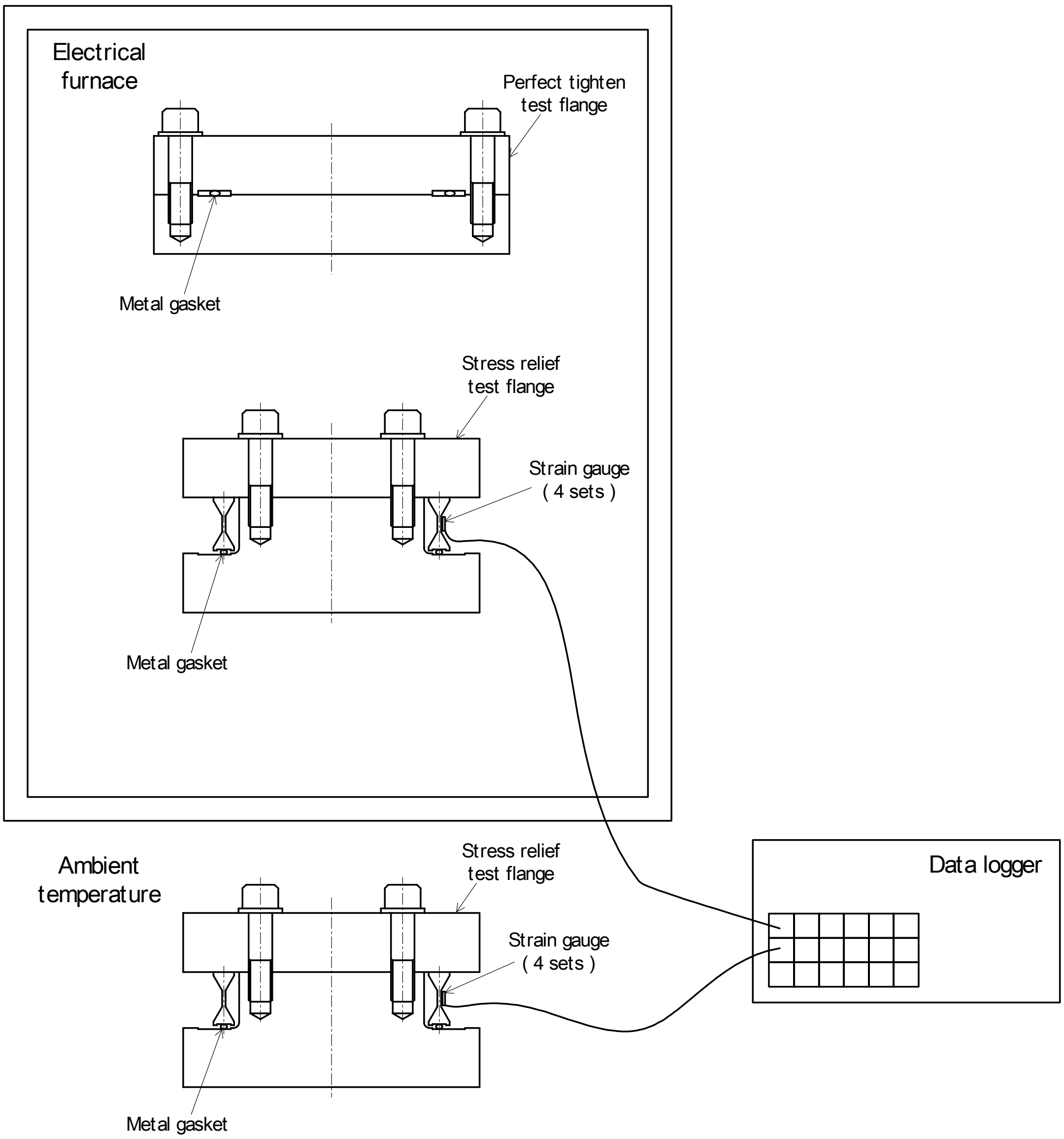


Fig.3 Overview of the experiment

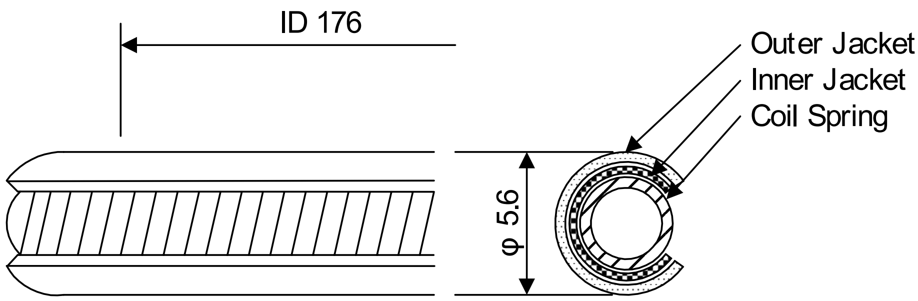


Fig.4 Gasket structure (Single)

Table 1 The condition of experiment

Gasket material	Gasket type	Test flange	Test temperature	Holding period
Outer jacket: Al Inner jacket: Inconel 600 Coil spring: Inconel X750	Single	Stress relief test flange	20°C,120°C, 200°C	Up to 800h
	Single	Perfect Tighten Test Flange	120°C, 200°C	
Outer jacket: Al Inner jacket: Inconel 600 Coil spring: Nimonic	Single	Stress relief test flange	120°C	

2.2 Result of experiment

We measured the reaction force of metal gasket continuously. These data are plotted black marks on Fig.5.
And the reaction force measured by perfect tighten test flange are plotted white marks on Fig.5.
The reaction force of the perfect tighten test flange agree well with the results of the value of the stress relief test flange. This result confirm that the measurement of reaction force used the stress relief test flange are proper.

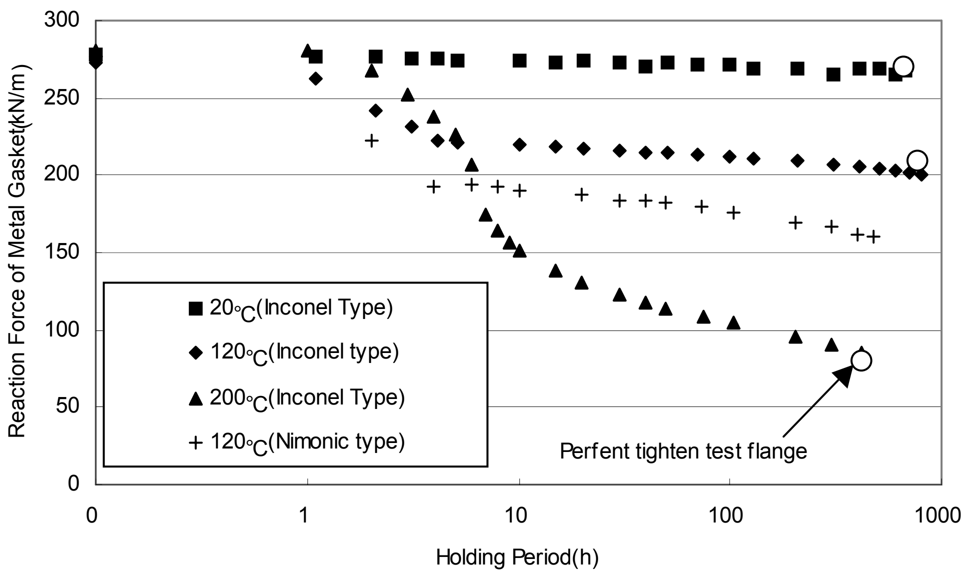


Fig.5 Result of experiment

The dimension of the gasket components after the long-term heating have been measured. The dimension of gasket components is shown in Fig.6, the dimension decrease of each component is Fig.7 and the section sample of metal gasket is shown in Photo.1.

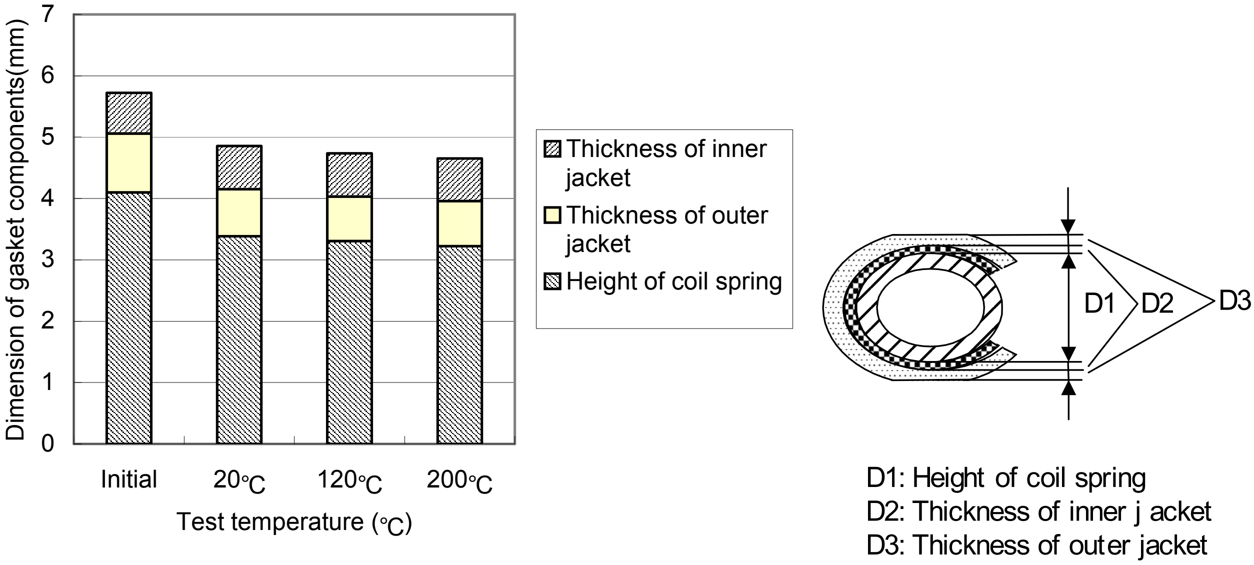


Fig.6 Dimension of the gasket components after the long-term heating

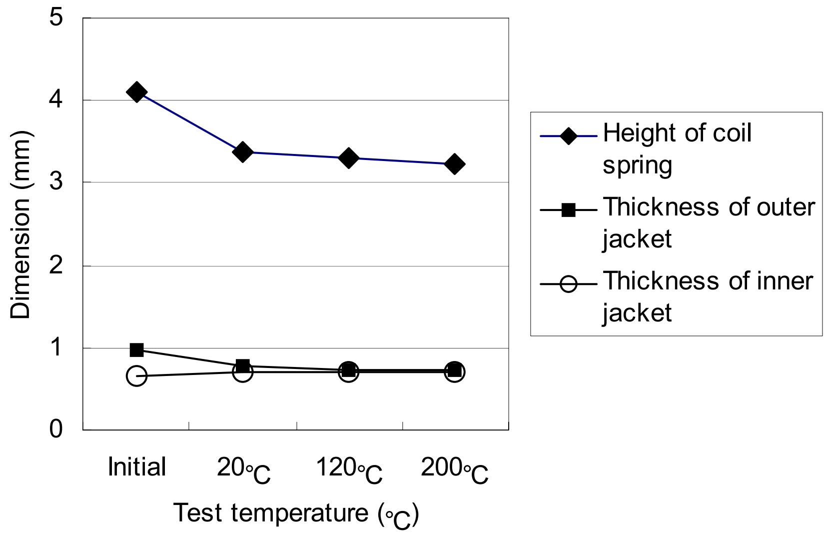


Fig.7 Dimension decrease of each component

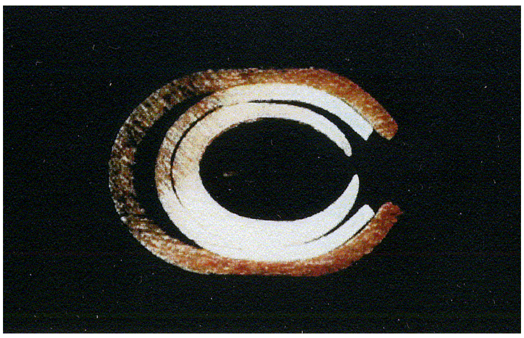


Photo. 1 Gasket section after long-term heating (120°C)

3. Mechanism of decrease of reaction force of metal gasket

The reaction force of metal gasket decrease during the first several hours in the result of 120°C and 200°C as shown in Fig.5. After that, the reaction force become stable and it gradually decrease. The rapid decrease of reaction force at room temperature do not apper, the reaction force is stable. This phenomenon can be explained as follows.

First of all, the test flange tigetened at room temperature is inserted in the electrical furnece and the temperature of metal gasket increases during several hours.This rise of temperature causes the decrease of material strength. The materials of metal gasket are as folloows;

Outer jaket: Alminium
Inner jaket: Inconel 600
Coil spring: Inconel X750

The material of inner jaket and coil spring are inconel, these materials strength do not change at these test temperature range, but the strength of outer jaket "Al" fall down according to the temperature rise. The strength of outer jaket fall down and the thickness of outer jaket decrease. This causes the decrease of the coil spring reaction force and resulted the sudden change of gasket reaction force at initial stage.

The mechanism of initial rapid decrease of reaction force is explained in the fig.8.

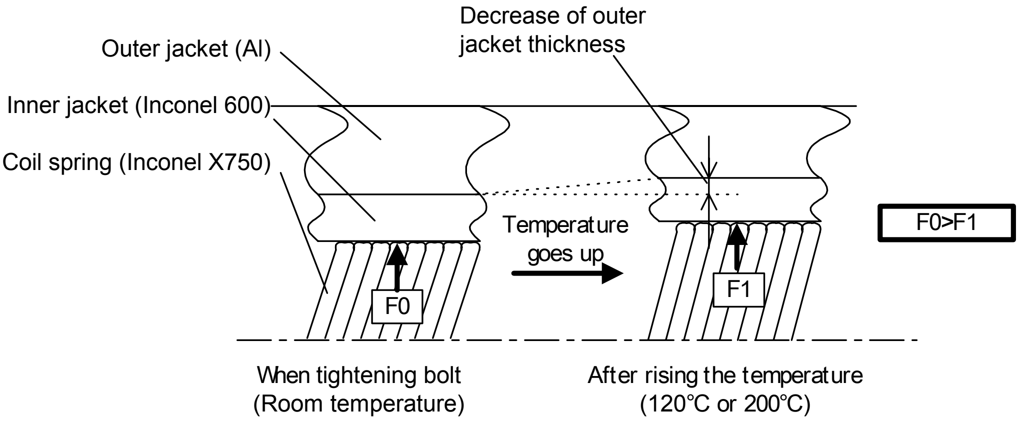


Fig.8 The mechanism of reaction force decrease

We compared the material strength and reaction force at room temperature, 120°C and 200°C to verify this theory. The comparison is shown in Table 2. In this comparison, average value of 0.2% yield strength and ultimate strength is used for material strength because plastic deformation generated in outer jacket. Decrease ratio of reaction force and material strength agree well. This result is proved that this theory is appropriate.

Table 2 The comparison of material strength and reaction force

Temperature (°C)	Decrease ratio	
	Reaction force (F_1/F_0)	Material strength ($\sigma_{av1}/\sigma_{av0}$)
20	1.0	1.0
120	0.81	0.76
200	0.54	0.50

F_0, F_1: See Fig.8
σ_{av0}: $(\sigma_y+\sigma_u)/2$ (at room temperature)
σ_{av0}: $(\sigma_y+\sigma_u)/2$ (at 120°C, 200°C)

And after stable of reaction force after several hours, the reaction force decrease gradually. This decrease is caused by the thickness change of outer plate and haight change of coil spring as shown in Fig.6 and Fig.7. Compared with the influence of thickness change of outer plate and haight change of coil spring, the latter is dominant for the reaction force decrease, because the deformation ratio of the latter is bigger than it of the former. Generally, creep deformation does not apper in alminium and inconel material at room temperature. Especially for inconel, creep deformation does not apper at 200°C. Nevertheless, the reaction force fall down gradually. It seems that these phenomenon is minute creep relaxation at low temperature. Some previous studies proposed that creep relaxation of metal gasket can be expressed by the equation as follows [2];

$$F=A - B(\ln(1+Ct)$$

F : Reaction force
A : Coefficient
B : Coefficient
C : Coefficient
t : Time(h)

These coefficients are able to evaluate according to the stress relief examination. The evaluation equations at each temperature are as follows;

20°C : $F=278-1.64\ln(1+0.775t)$
120°C : $F=221-3.90\ln(1+0.136t)$
200°C : $F=152-17.1\ln(1+0.139t)$

The comparison between the equation and test result are shown in Fig.9. The equation and test result agree well, this result is proved that this theory is appropriate.

Some previous study proposed that the Larson-Miller evaluation of reaction force for long-term is efficient. We arrange the result by Larson-Miller parameter as shown in Fig.10, the efficiency of Larson-Miller evaluation is confirmed in the same manner as previous study except the initial stage.

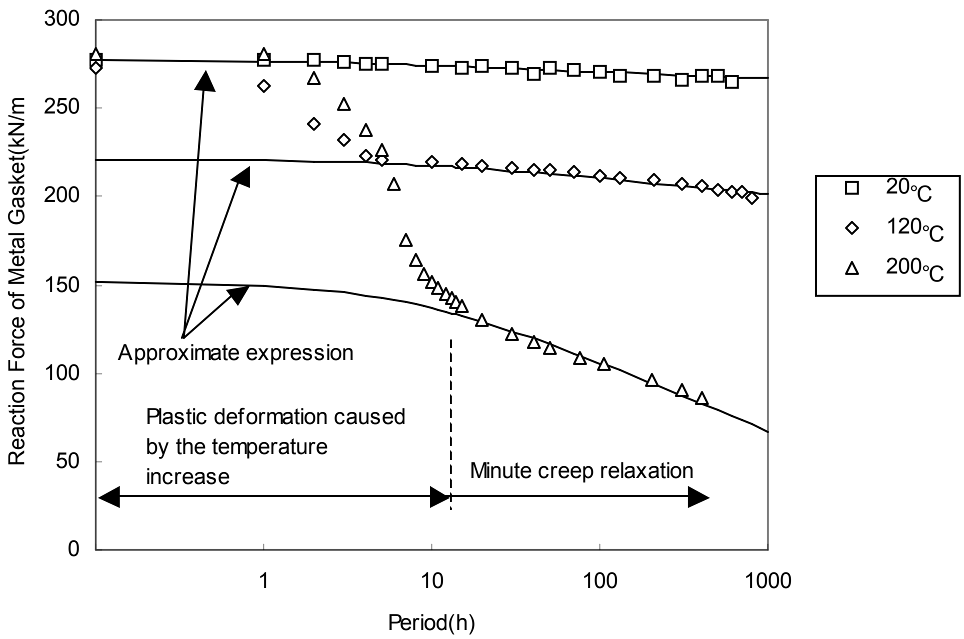


Fig.9 The comparison between the equation and test result

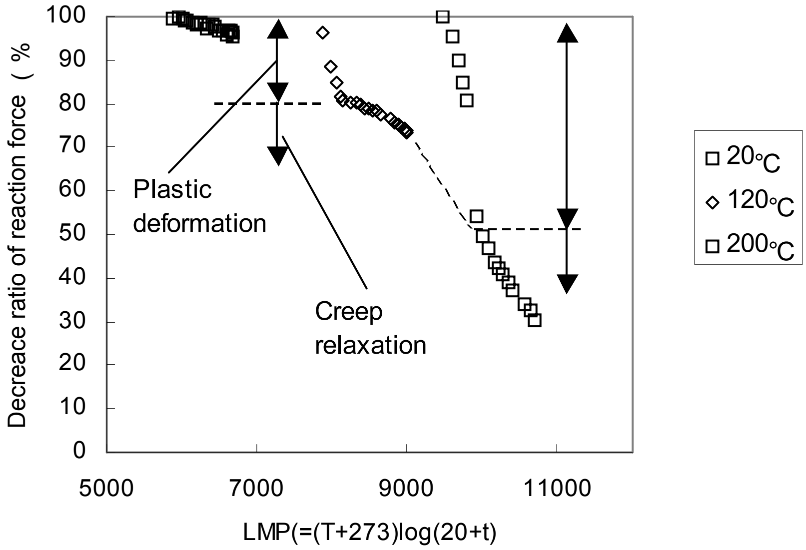


Fig.10 The arrange at Larson-Miller parameter

4. Conclusion

The temperature of metal gaskets initially tightened to the flange of the casks is not so high, almost equivalent to the ambient temperature, but it increase after the tightening due to the decay heat of spent fuels. Then the property of metal gasket may change as temperature increase. If the tightening torque of bolts is not appropriate(there are small gap at the contact surfece), this change may cause the decrease of reaction force against the tightening load of the bolts to these gaskets, and results in loosening of bolts. It is important that the metal gasket have to be perfectly pressed into the gasket groove. It is necessary to take an appropriate margin in the tightening load of the bolt. It is easy to evaluate that the reaction forces of the metal gasket in storage condition according to Larson-Miller parameter or relaxation of the gasket material, but the decrease of the reaction forces of the metal gasket just after the loading is not able to evaluate by these method. It is necessary to evaluate the reaction forces according to plastic deformation property of the metal gaskets so as to fasten the gaskets safety.

References

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[2] O,Kato, S.Saegusa: Study on Long-term Sealability of Gaskets for Spent Fuel Storage Cask(No.2),CRIEPI Rreport U94029, (1994).