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Evaluation of Hoisting Loads of Refueling Machine during Fuel Off-loading

Chang, Sang-Gyoon, Kim, In-Yong, Sohn, Gap-Heon,
NSSS Engineering project Division, Korea Power Engineering Company, Inc.
Daejeon, Korea, sgchang@kopec.co.kr

1. Introduction

The hoisting loads of the Refueling Machine (RM) during fuel off-loading are analyzed and evaluated. These hoisting loads should be measured and precisely controlled within the range of pre-set values to ensure the integrity of the fuel and the related equipment. In this study for hoisting loads, several input parameters in determining the range of pre-set values are provided and reviewed in a viewpoint of the operation efficiency in the core.

2. Analysis for RM hoisting loading for fuel off-loading

The fuel handling system (FHS) consists of equipment used for receiving and transporting fuel assemblies. The basic requirements for this system are to handle the fuel assemblies in a safe and reliable manner [1]. The mechanical or electrical safety devices are designed for the system to prevent the fuel assemblies from being damaged and posing a radiation hazard to personnel [2].

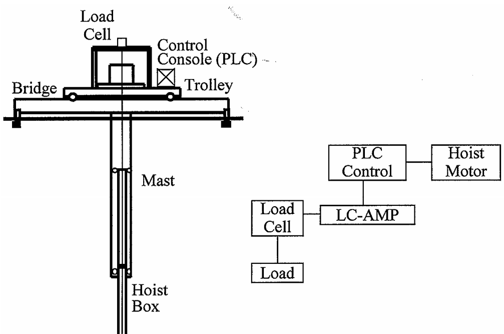

Fig. 1 Configuration of hoisting and measuring components for RM

The RM, which is main equipment of FHS, consists of a traveling bridge and trolley which handles fuel in the core. The mast, the hoist box and the grapple are located on the hoisting frame of the trolley as shown in Fig. 1. The load cell and the control console used for measuring hoisting loads and controlling the hoisting operation for interlocks also located on the same structure. Fig. 1 are also shows a control path for receiving and transmitting load signals. The hoisting load signals measured using a load cell are controlled by the control console with PLC (Programmable Logic Controller) and hoisting motor through the load cell amplifier (LC-AMP). It is essential that we know operating sequences for fuel off-loading to clarify hoisting loads in the core. The detailed operating sequences for fuel off-loading are shown in Fig. 2.

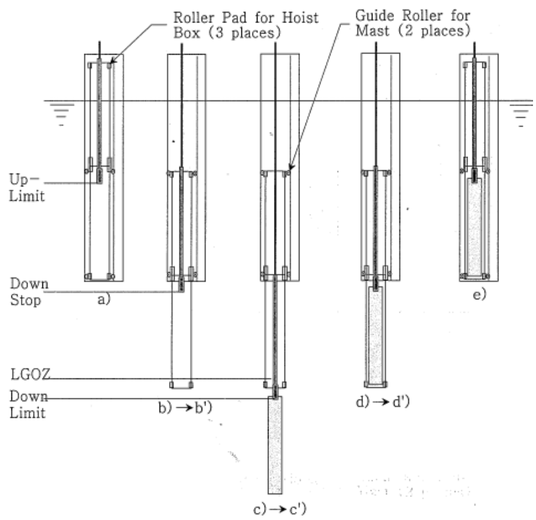

Fig. 2 Operating sequences for fuel off-loading in the core

Fig. 2 can be summarized as follows; a) RM moved over the reactor with up-limit elevation for grappling a fuel in the core. b) The hoist box and the grapple are lowered until the hoist box is latched at the down stop elevation and the grapple is only starting to lower (refer to b' of Fig. 2 and Fig. 3). In the sequences of a) and b), there are the facial contacts between the guide rollers inside of the mast and the roller pads located at the corner of the hoist box. c) The grapple is lowered, closed for grappling the fuel and slightly raised (refer to c' of Fig. 2 and Fig. 3). The grapple should be open for grappling in the Lower Grapple Operating Zone (LGOZ). d) The grappled fuel is raised into the hoist box after grappling in down limit. The raised fuel is completely positioned inside of the hoist box in hoist position of the Fuel Region. The weight of the fuel and the grapple is gauged in this region and the weight for hoist box is added at d' (refer to Fig. 2 and Fig. 3). e) The fuel and grapple are altogether raised with the hoist box until the hoist reaches up-limit elevation. We call the range of hoist position from d' to e as the Fuel + Hoist Box Region. There are some slow zones and overload bypass zones in the transition positions to prevent hoist from tripping due to rapid changes of hoisting load during fuel off-loading. The same practices are also applied for fuel reloading sequences. The input parameters for the range of pre-set values for PLC control can de determined by the component such as a fuel, a grapple and a hoist box. The allowable shear load for space grid (f_{SG}), which provides lateral supports to a fuel as chosen for the fuel integrity, should be considered. The loads combination of overload and underload for PLC set points at each region are defined in Table 1.

Table 1 Load combination of overload and underload for PLC set points

Region	Loads combination for PLC set points	
Fuel Region (c' to d of Fig. 2)	Overload	Weight (grapple + min. fuel) + f_{SG}
	Underload	Weight (grapple + max. fuel) - f_{SG}
Fuel + Hoist Box Region (d' to e of Fig. 2)	Overload	Weight (grapple + min. Fuel + Hoist box) + f_{SG}
	Underload	Weight (grapple + max. Fuel + Hoist box) - f_{SG}

3. Evaluation of RM hoisting loads for fuel off-loading

The RM hoisting loads varying according to hoist position in the core are shown in Fig. 3.

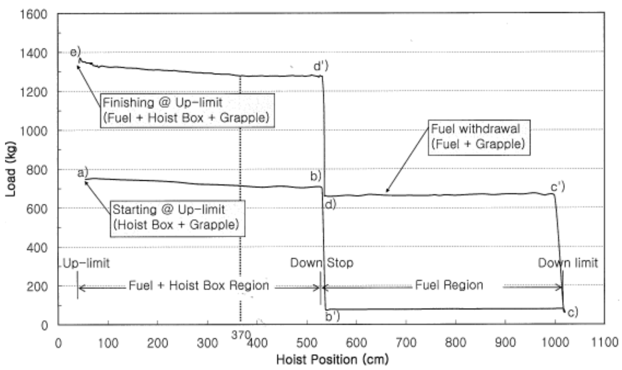

Fig. 3 RM hoisting loads at hoist position

The fuel off-loading in the core is starting at up-limit position (a of Fig. 3) and finishing at up-limit position (e of Fig 3) with a grappled fuel. While the sequences of b' to c and c' to d have constant hoisting load conditions without any load changes, hoisting loads in the sequence of a to b and d' to e are decreased and increased to approximately 60 kgs, respectively. It is believed that these loads are derived from the dynamic drag force and the buoyancy effect for the hoist box in water. These effects are finished and started at 370 cm of hoist position. Fig. 3 shows that these two effects can be negligible below 370 cm of hoist position. The overshooting of hoisting loads due to the inertia force and the speed transient can occur, but the establishment of slow speed zones and load bypass zones can prevent hoisting load from being overshot at these areas as mentioned above. The other factor to be considered is friction force occurring between guide rollers inside of mast and roller pads located at the corner of the hoist box in a to b and d' to e of Fig. 3. These parameters in determining the range of pre-set values are the important factors to protect a frequent trip of hoist due to the increased hoisting loads in the core. The additional loads imposed during fuel off-loading are summarized in Table 2.

Table 2 Main operating loads and additional loads

Region	Weight	Additional loads	Hoist Position
Fuel Region	Grapple + Fuel	none	c' to d
Fuel + Hoist Box Region	Grapple + Fuel + Hoist box	- Hoist box buoyancy - Friction effect	d' to e

The minimum and the maximum fuel weights are used in the load combination as shown in Table 1. If the difference between two values for fuel weight gets bigger, the operating range for PLC set points gets smaller comparing with the case of using normal weight. In case these two different fuel weights are used as inputs for load combination, it is necessary to review their adequacy as inputs for PLC set points in respect of operation efficiency.

4. Conclusions

The hoisting loads of refueling machine during the fuel off-loading are analyzed and evaluated. The buoyancy effect for the hoist box in water and the friction effect occurring between the guide rollers of the mast and the roller pads of the hoist box are reviewed as input parameters. By considering these effects in the Fuel + Hoist Box region, we can protect the hoist of the Refueling Machine against frequent trips and enhance the operation efficiency in the core.

REFERENCES

[1] 과기부 령 92 호, 원자로시설 등의 기술기준에 관한 규칙, 2006. 7. 19.

[2] ANSI/ANS-57.1, Design Requirements for Light Water Reactor Fuel Handling Systems, 1992 (Re-affirmed 1998).