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種別(和文)	論文要旨
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（博士課程）
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論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	機械 機械	系 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of	（ 工学 ）
学生氏名： Student's Name	Rubani Firly		指導教員（主）： Academic Supervisor(main)	因幡 和晃	
			指導教員（副）： Academic Supervisor(sub)		

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

This dissertation concentrates on analyzing the relationship between damage from cavitation bubble collapse and solid material properties through a coupled fluid-solid numerical simulation. From fluid perspective, bubble collapse impact load (BCIL) and impact energy are used to quantify the intensity of damage. From solid perspective, acoustic impedance and plasticity are used to explain the cavitation damage mechanism on metals and polymers which are commonly used as main material and coatings for hydromachinery components. The brief summaries of each chapter are:

Chapter 2, we examined the numerical scheme of ANSYS Autodyn to decide which parameters that affect the dynamics of bubble collapse and its impact to solid material. Grid verification was conducted. It was found that 34 nodes per 0.5 mm bubble radius gives a stable result. Validation against two cases: laser-induced bubble inside gelatin gel and shock-induced bubble collapse near Lucite wall were done. The shock-front and vapor bubble radius inside 10%wt gelatin from present simulations were shown to be in good agreement with experimental and numerical results of Oguri and Ando (2018). The averaged impact pressure at Lucite wall also shows good agreement with experiment results by Shima et al. (1989) and numerical results by Johnsen and Colonius (2008).

Chapter 3, we developed a numerical model of shock-induced collapse of air bubbles near metals (titanium, SUS304, Al2024) and polymers (adiprene, epoxy, and polyethylene) with standoff distance 1.06 inside long and narrow channels with width 1 mm. Three different material constitutive models-purely elastic, elastic-perfectly plastic, and strain-hardening-were investigated. The elastic-perfectly plastic model gives highly comparable results of maximum BCIL against acoustic impedance compared with cavitation erosion test of several metals and polymers of Hattori and Itoh (2011). The impact energy analysis for metals shows no significant change between three constitutive models. However, for polymers, large discrepancies were found in the elastic model. This indicates two things: in metals, BCIL can be defined by acoustic impedance, whereas in polymers, it is heavily affected by yielding. However, further evidence is needed to explain this damage mechanism.

Chapter 4, we continued to utilize the same numerical model, with thickness varied from 5 to 0.5 mm and only elastic-perfectly plastic model was analyzed. Magnesium, Teflon, and nylon were added to the material for filling the acoustic impedance data in the middle range. Maximum BCIL acting on the solid surface was plotted against acoustic impedance. It was found that for metals, BCIL decrease as the impedance decreases. There is a significant increase in maximum BCIL value for 0.5 mm thickness, indicating that it is affected by wave propagation behavior inside material. For confirming the mechanism, Continuous Wavelet Transform analysis was conducted for BCIL acting on the surface. It was confirmed that for metals, BCIL propagates with similar frequency as the elastic wave (compression and shear). The significant increase occurred due to superposition between elastic wave frequency and the counterjet duration of visibility. Hence, it can be concluded that the damage mechanism of metals can be explained by BCIL and acoustic impedance.

For polymers, no inference has been found to elastic properties. Therefore, plastic deformation behavior was analyzed in detail. Image analysis of apparent pit growth was computed through MATLAB. The pit volume growth rate shows high correlation ($R^2 > 0.9$) of non-linear relationship with yield strength, meaning that the initial plastic deformation phase depends on yield. To visualize the incubation-like period in

the plastic deformation, the averaged final pit depth and pit volume were estimated. High correlation ($R^2 > 0.9$) with non-linear relationship with yield strength was also found.

Evidence from real-time video of cavitation erosion test of epoxy (Hibi et al., 2018) shows several micro-holes (pits) which then initiates a larger crack. The initiation of holes relates to pit volume observed in this study. The larger the size of initial holes, the more severe the erosion can occur. Therefore, pit volume and cavitation volume loss (CVL) are related. Barletta et al. (1983) found a U-shaped relationship between CVL and Shore hardness of 27 polymers through cavitation erosion test. It can be deduced that the non-linear relationship between pit volume and yield found in this study explains the left-side portion of the U-shaped graph. Hence, cavitation damage in polymers with low yield or hardness occurred due to yielding or low-cycle fatigue.

The right-side portion (high hardness and yield polymers) cannot be explained owing to limitations of polymers used in this study. However, deduction can be made as follows: high yield strength causes the jet emitted from bubble collapse to not reach the critical impact velocity of the materials; thus, the solid particle does not skid hence no instant plastic deformation. This resembles the cavitation damage mechanism of metals. Therefore, the damage mechanism for polymers with high yield or hardness is similar as that found in metals, which occurs because of repeated load and high-cycle fatigue.