論文 / 著書情報
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題目(和文)	超音波後方散乱による内表面の周期的三角形状の評価
Title(English)	EVALUATION OF PERIODIC TRIANGULAR PROFILE OF INTENAL SURFACES BY ULTRASONIC BACKSCATTER
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THESIS OUTLINE

Periodic surface structures appear in sophisticated technologies and characterization of periodic surfaces is crucial for a variety of engineering applications, such as optically or tribologically functional surfaces, machined surfaces, and screw threads. Most techniques for characterizing the surface profile are only suitable for accessible surfaces. In reality, the internal surface morphology and profile of mechanical components are important properties to ensure the products quality. In this manner, the fundamental study to quantitatively characterize both the pitch d and height h of internal surfaces having the periodic triangular profile, as a first step, by the ultrasonic backscatter method carried out from the back side is presented.

In chapter 1, the related literature reviews as well as the significance and scope of the present study are addressed. This lead to the development of ultrasonic backscatter method for characterizing the internal surfaces having periodic profile, which is presented in following chapters.

In chapter 2, an ultrasonic pulse-echo technique is investigated to evaluate the pitch of internal surface having periodic triangular profile based on the diffraction grating theory for oblique incidence, the applicability of such proposed technique is validated by both numerical simulation and experiment. It is observed that when the incident angle is larger than 45º, this technique provides a good accuracy because the noise from the coherent component in specular direction is negligible. This technique can be applied by using not only P-wave but also S-wave. SH-wave shows better results compared with SV-wave due to the effect of mode conversion. It should be noted that SH-wave is more sensitive than P-wave since SH-wave has shorter wavelength than P-wave.

In chapter 3, an ultrasonic backscatter polar scan technique to evaluate the height of internal surfaces having periodic triangular profile based on the maximum efficiency of a reflection grating, which is related to the blazed angle of triangular profile, is demonstrated. The problem of this technique is that anomalies of different types as well as of the same type merge into each other, making it difficult to distinguish between them, and makes the efficiency curves become complicated. However, according to numerical analysis, the ultrasonic backscatter polar scan technique has possibility to characterize the periodic triangular surfaces having medium blaze angle ($10º < \theta_B < 18º$), and low-anomaly blaze angle region ($18º < \theta_B < 22º$) with percentage of error lower than 10%. In the range of special low-anomaly and high blaze angle, the anomalous wavelength can be used to evaluate h with higher accuracy than using the maximum efficiency's one.

In chapter 4, the ultrasonic backscatter master curve technique to evaluate the height of internal surfaces having periodic triangular profile is presented. This technique is based on the master curve equation constructed by numerical simulation data of first peak normalized amplitude in wave-number response function of ultrasonic waves scattering from periodic triangular surfaces with 60º of incidence angle. It is observed that the master curve depends only on the ratio of h/d, and unchanged regardless with the pitch d. Numerical and experimental validations are conducted to prove the ability of this technique with good accuracy in the measurable range of d and h/d from 0.4 mm to 1.6 mm and from 0.2 to 0.5, respectively. However, master curve equation should be reconstructed for other surface profiles.

In chapter 5, an ultrasonic backscatter technique is investigated based on Kirchhoff approximation combining with diffraction grating theory to characterize the internal surfaces having periodic triangular profile. The relationship of reflection coefficient from normal incidence with the pitch and height of surface profile are studied theoretically using Kirchhoff theory in respect to different frequencies. It is observed that an appropriate selection of f is necessary to obtain the optimum results. The estimated h values from proposed technique provide a good accuracy in the range of $h/d \leq 0.4$ for frequency 4.5 MHz with ±5% of errors. By using frequency 10 MHz, the surfaces having small pitch, e.g. 0.4 mm, can be characterized with ±10% of errors in the range of $h/d \leq 0.4$. The Kirchhoff theory technique is proposed the best one among others, since it is applicable to any periodic surfaces, such as one having sinusoidal, elliptical, and corrugated profiles.

In chapter 6, general conclusions and future works of the present study are summarized. Throughout the work, the main objective of the present study, which is to quantitatively characterize the internal surfaces having periodic triangular profile by ultrasonic backscatter techniques, has successfully been achieved. It is suggested

that contribution of the diffuse field scattering from periodically rough surface should be introduced into the Kirchhoff approximation, since the intensity the diffuse field scattered from rougher surfaces becomes the dominant part. Moreover, 3D periodic surfaces with other periodic profiles, or imperfectly periodic surfaces having a number of periodicities and effect of surface waviness should be investigated. In addition, the solid-liquid interfaces of internal surfaces for practical inspections, such as the pipes in service with fluid flowed inside, can be a research proposal in future.