主　論　文　の　要　約

論文題目　**Study on Superficial Layer Delamination for Investigation of Frictional Damage Characteristics at Skin—Cuff Contact Systems**
(皮膚-カフ接触部における摩擦損傷特性究明のための皮膚表面層剥離に関する研究)

氏　　名　**毛　雪偉**

論　文　内　容　の　要　約

The thesis mainly focuses on mechanical characteristics of the skin superficial layer delamination, which is considered to be the major phenotype of the skin friction damage typically caused by the undesired physical stresses at the human skin—robot cuff contact system. The thesis consists of six chapters. The first chapter introduces the background of the research. Chapter 2 demonstrates the parametric identification for investigating the superficial delamination which causes skin friction damages. Chapter 3 exhibits the specific experimental materials applied for the tests of skin friction traumas. Main experimental techniques are also described in this chapter. Chapter 4 demonstrates a safety verification method developed for helping the physical assistant robot users prevent the skin friction blisters from being generated during the uses. Chapter 5 provides a detailed analysis of mechanical characteristics for scratch damages, which is completed on a specific kind of dummy skin with stable properties. In Chapter 6, the major conclusions are made from the investigations into friction damage characteristics at human skin—robot cuff contact systems.

In chapter 2, a parametric identification is performed for studying the superficial layer delamination at the initial stage of skin frictional damage. Influences of the significant parameters on skin frictional damages are summarized based on the investigations of skin friction blister or abrasion. Variations of mechanical properties at the skin—cuff contact surfaces are associated with the development of skin frictional damage, which allows us analyze varying skin—cuff contact mechanical properties acting as an alarm of the initial skin frictional damage. Regarding skin friction blister, the relationship between tangential traction—rubbing time conditions and the generation of friction blisters is intensively analyzed in this chapter, which enables us to develop a safety verification method for providing inherently safe use conditions for physical assistant robot users. In addition, a relationship between abrasion conditions, such as indentation depth, tip velocity and abrasion frequency, and abrasion times is also investigated for performing further evaluation of the skin—cuff contact conditions.

Chapter 3 describes specific experimental techniques applied for the skin frictional damage investigations performed throughout the studies in this thesis. Considering the requirements of avoiding the ethical controversy caused by conducting experiments on human subjects, porcine skin and dummy skin of our own development are used in the study, substituting human skin for the following two purposes, an analytical model for human skin—robot cuff contact mechanics and the establishment of a safety verification method for physical assistant robot users. As the scale of initial skin friction blister or abrasion damage is microscopic, this chapter describes unique methodologies for examining appearances of the damaged skin samples. Following an introduction of the selection for experimental apparatus, this chapter shows major experimental procedures for different purposes, which are able not only to simulate practical human skin—robot cuff contact conditions but also to obtain sufficient information for a further analysis of skin frictional damage generation conditions.

In Chapter 4, a safety verification method is developed for providing physical assistant robot users with an inherently safe condition range where friction blisters are generated with negligible probability of occurrence. *In vitro* porcine skin's characteristics regarding the friction blister generation are identified to confirm the feasibility of selecting porcine skin as a substitute for human skin. Based on the censored experimental results obtained by microscopic observations, a nonparametric estimation method is introduced for calculating the survival function of porcine skin samples. An inherently safe region not to cause friction damage is found in a relationship between tangential traction and rubbing time. Accompanied with friction blister generation conditions obtained in the previous experiments conducted on human subjects, the inherently safe threshold is further enhanced in this chapter, and its feasibility in practical utilizations of physical assistant robots is also verified using a safety validation test for a period of human skin—robot cuff interactions when a robot user is performing a motion of “stand-up and sit-down".

Chapter 5 describes mechanical characteristics of a dummy skin—cuff model contact surface during a development process of skin abrasion damage, and significant varying tendencies of friction coefficient are found to be a clue for an irreversible abrasion damage. According to the previous investigations of the scratch-induced damage mechanism, three physical factors, indentation depth, tip velocity and abrasion frequency, are regarded as the most significant factors for the skin abrasion damage caused at the contact conditions in the aspect of human—robot interactions. Different influences of these physical factors on abrasion damages are subsequently determined with abrasion times in the analytical model. Using the same experimental system, fresh porcine skin samples also exhibit similar varying tendencies of friction coefficient. Accompanied with cryosection observation results, the experimental methodology is proved to be feasible for evaluating practical human skin—robot cuff contact conditions. Chapter 6 makes a brief summary of the major investigations performed in the thesis and the important conclusions regarding the friction damage characteristics at human skin—robot cuff contact systems. Moreover future perspectives of the thesis were also introduced briefly considering requirements for applying the investigations results concluded in the thesis to actual uses of physical assistant robots.