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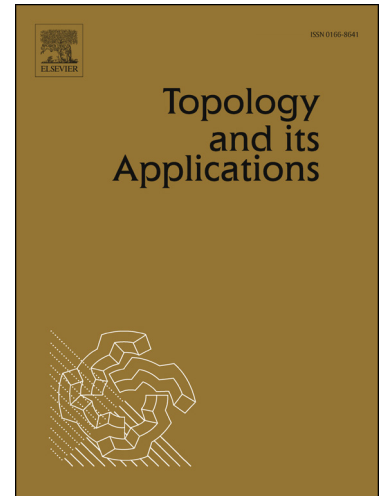
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# RIBBON-CLASP SURFACE-LINKS AND NORMAL FORMS OF IMMERSSED SURFACE-LINKS

SEIICHI KAMADA AND KENGO KAWAMURA

*Dedicated to Professor Taizo Kanenobu, Professor Yasutaka Nakanishi, and Professor Makoto Sakuma in celebration of their 60th birthdays.*

ABSTRACT. We introduce the notion of a ribbon-clasp surface-link, which is a generalization of a ribbon surface-link. We generalize the notion of a normal form on embedded surface-links to the case of immersed surface-links and prove that any immersed surface-link can be described in a normal form. It is known that an embedded surface-link is a ribbon surface-link if and only if it can be described in a symmetric normal form. We prove that an immersed surface-link is a ribbon-clasp surface-link if and only if it can be described in a symmetric normal form. We also introduce the notion of a ribbon-clasp normal form, which is a simpler version of a symmetric normal form.

## 1. INTRODUCTION

In this paper an *immersed surface-link* means a closed and oriented surface generically immersed in  $\mathbb{R}^4$ . When it is embedded, we also call it a *surface-link* or an *embedded surface-link*. An immersed surface-link with one component is called an *immersed surface-knot*. Two immersed surface-links are said to be *equivalent* if they are ambient isotopic.

An embedded surface-link is called a *trivial surface-link* if it is the boundary of a disjoint union of embedded handlebodies in  $\mathbb{R}^4$ . An embedded surface-link is said to be a *ribbon surface-link* if it is the boundary of immersed handlebodies in  $\mathbb{R}^4$  whose multiple point set is a union of ribbon singularities. (The definition of a ribbon singularity is given in Section 2. For an immersion  $f : M \rightarrow \mathbb{R}^4$  of a bounded 3-manifold  $M$ , the *boundary* of the immersed 3-manifold  $f(M)$  means the image  $f(\partial M)$  of the boundary  $\partial M$  of  $M$ .)

**Definition 1.1.** An immersed surface-link is said to be a *ribbon-clasp surface-link* if it is the boundary of immersed handlebodies in  $\mathbb{R}^4$  whose

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*Key words and phrases.* Surface-link; ribbon-clasp surface-link; ribbon singularity; clasp singularity; normal form.

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