Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 50 (2016) 76 – 81

www.elsevier.com/locate/procedia

26th CIRP Design Conference

Improving design efforts and assembly efficiency of rotor blade carriers through modularisation

Simon Kaczmarek[a] *, Sebastian Hogreve[a], Andreas Greten[b], Marco Schröder[b] and Kirsten Tracht[a]

[a] *Bremen Insitute for Mechanical Engineering, University of Bremen, Badgasteiner Straße 1, 28359 Bremen, Germany*
[b] *HAWART Sondermaschinenbau GmbH, Handwerksweg 8, 27777 Ganderkesee, Germany*

* Corresponding author. Tel.: +49-421-218-64832. *E-mail address:* kaczmarek@bime.de

Abstract

Rotor blade carriers are custom build for each wind turbine rotor blade type. This causes high efforts in design processes, assembly preparation and raises the number of product variants. This paper presents an approach to apply the concept of modularisation on rotor blade carriers to induce serial production methods, optimise the easiness of assembly and reduce design efforts per order by using standardised modules in combination with few custom designed parts. The design of an easy to operate mechanical interface for module connection enables variability and life cycle extension by providing the option to re-use and re-combine modules.

Peer-review under responsibility of the organizing committee of the 26th CIRP Design Conference

Keywords: variety management; modularisation; assembly

1. Introduction

The increase in size of onshore and offshore wind energy systems [1] in combination with new design and production methods for rotor blades causes a high number of rotor blade variants, which are produced during a limited time frame. Design features like the number of fixation bolts, diameter on which the fixation bolts are placed, weight, centre of mass or geometrical features like the length of the rotor blade vary and require adapted handling tools. Therefore, rotor blade carriers (RBC) are currently custom build for each rotor blade type. This leads to high efforts in design, high product variety and it prevents the application of approaches of serial production.

A rotor blade requires two carriers for handling, storage and transportation. These carriers mainly consist of cast steel profiles. The root carrier is attached to the bolts at the root of the blade while the tip carrier includes a rotor blade socket, which fixates the tip of the rotor blade. The tip carrier is always build as a three-dimensional carrier in order to avoid tilting of the carrier and therefore forces and momentums on the rotor blade. The root of a rotor blade is by design a fixation point and therefore able to deal with forces and momentums. Consequently it is possible to design the RBC as a two- or three-dimensional carrier. Fig. 1 shows different types of rotor blade carrier configurations.

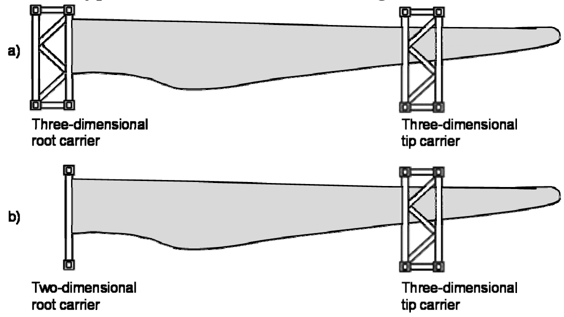

Fig. 1. (a) three-dimensional root and tip carrier, (b) two-dimensional root carrier and three-dimensional tip carrier

The process for the order of a conventional RBC has been structured in cooperation with a special purpose machine

Peer-review under responsibility of the organizing committee of the 26th CIRP Design Conference
doi:10.1016/j.procir.2016.05.021

manufacturer and is shown in Fig. 2. Starting with the intake of an order, the process takes 10-16 weeks depending on the complexity of the carrier and the volume of the order. As the first step the design process is performed in order to create a rotor blade specific carrier including special demands of the customer.

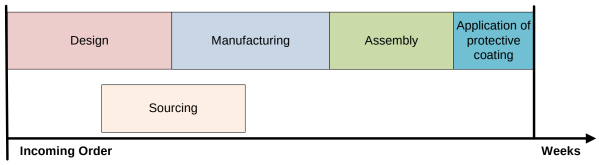

Fig. 2. Simplified illustration of the process chain for a conventional RBC

The sourcing process starts after the first features have been fixed. Pre-production, welding processes and assembly are conducted afterwards. The application of a surface protection is necessary to meet the requirements towards durability of the RBC especially for sea transportation.

From each separate RBC design project certain findings and experiences can be deduced as lessons learned and consequently provide help for comparable future orders. Nonetheless, a big amount of work that goes into the design phase is spend on recurring tasks and the assembly processes are, due to differences in design, dimension and quantity, not suitable for standardisation approaches.

It became visible during a process analysis, that the products as well as the process steps from different projects show many similarities, that have not been visible as each RBC type is handled as an individual product with individual design. To make use of these similarities and to improve the design efforts and assembly efficiency the concept of product modularisation has been applied on RBC in a cooperation project with a special purpose machine manufacturer and is presented in this paper. By using the modularisation approach it is possible to transfer big amounts of repeated design efforts into a one-time design project and to separate standardised production and assembly processes from order specific efforts.

2. Modularisation

Modularisation is a concept that allows the configuration of different product variants using components from a limited set of modules [2]. This concept is generally based on the segmentation of a system into different subsystems, that each fulfill a designated function [3]. It can be distinguished between basic functions, supporting functions, special functions and order specific functions [4]. Combining the different modules and their functions into a working product requires the connection of the modules using interfaces. Their design is essential for the success of a modular product [5], as forces, working fluids or information have to be transferred securely.

A common approach for the realisation of product modularisation is to use manufacturer construction sets. The advantages for the manufacturer are for example:

- Quotations, project plans and designs can be based on existing material, as most of the effort for creation is performed in a one-time-process upfront.
- Order or customer specific design efforts are only required for special design features which were not planned during construction or for very few customer specific modules.
- It is possible to extend the construction set with additional elements, that are not integrated into the set.
- Preparation processes, pre-assembly and scheduling of the production becomes easier when the products are well-known.
- Order processing in design and production can be speeded up using parallelisation approaches. The delivery readiness can be improved. [4]
- Scale effects can be incorporated. [6]

On the other hand, modularisation causes costs for the more complex development and design process and for overdimensioning of modules in order to be able to create different variants from the construction set [7]. Modularisation projects have been successfully conducted over a long time frame with different approaches [8] and in different industries. An example for modular steel construction products are guardrails for road traffic [9]. Even though approaches for modular load carriers are known [10] RBC have not yet been modularised.

3. Modular design of rotor blade carriers

The modular design of RBC is based on the analysis of different wind energy systems, their rotor blades and the related carrier designs. The results show an increase in power output of the energy systems as well as in length and in weight of the rotor blades. Consequently, the carrier designs need to be adapted to different influencing factors. A certain range of different varying factors has to be covered by the construction set.

3.1. Requirement specification and covered range of rotor blades for modular RBC

The requirement specification is based on a survey with more than ten companies from the wind energy and logistics sector to ensure the applicability of the modular concept for the future use with rotor blades. The most important requirements will be highlighted in the following:

- Basic functions: The RBC are supposed to be used for non-damaging and secure lifting and transportation of the rotor blades by road and sea. In addition, the RBC must be stackable threefold while containing a rotor blade for storage on land and transportation on a ship.
- Form of the RBC: The construction set is supposed to be used for the configuration of three-dimensional tip and root carriers and two-dimensional root carriers.
- Normative requirements: Guidelines and standards for road and sea transportation, constructional steelwork and lifting guidelines have to be followed in order to be allowed to use the modular RBC on public roads or for sea transportation.