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Concurrent engineering solution for the design of ship and offshore bracket parts and fabrication process

Tae-Won Kim[1], Sang-Sub Lim[2], Ho-Hyun Seok[2] and Chung-Gil Kang[3]

[1]*Sekjin Metal Co., Ltd., Busan, Korea*
[2]*Precision Manufacturing System Division, Mechanical Engineering, Pusan National University, Busan, Korea*
[3]*School of Mechanical Engineering, Pusan National University, Busan, Korea*

ABSTRACT: *Brackets in ships and offshore structures are added structures that can endure stress concentrations. In this study, a concurrent engineering solution was proposed, and a high strength low carbon cast steel alloy applicable to offshore structures was designed and developed. The yield strength and ultimate tensile strength of the designed steel were 480 and 600 MPa, respectively. The carbon equivalent of the steel was 0.446 with a weld crack susceptibility index of 0.219. The optimal structural design of the brackets for offshore structures was evaluated using ANSYS commercial software. The possibility of replacing an assembly of conventional built-up brackets with a single casting bulb bracket was verified. The casting process was simulated using MAGMAsoft commercial software, and a casting fabrication process was designed. For the proposed bulb bracket, it was possible to reduce the size and weight by approximately 30% and 50%, respectively, compared to the conventional type of bracket.*

KEY WORDS: Steel structure; Offshore structure; Bracket; Casting steel; Reduction of volume.

INTRODUCTION

The need to develop low temperature and high strength casting steel for offshore structures has increased in line with the expanding resource development in areas, such as the Arctic Ocean. The brackets used for vessels or lathe structures are normally "ㄱ" or "T" shaped, and are used as supplementary structures to accommodate stress concentrations on the corners where columns meet, or where a beam and a triangular shape occurs. For a large bracket, the end part is designed using a curve to reduce interference, weight, and stress transfer (Lee, 2008).

A bracket for a vessel and structure is manufactured in plank form. When reinforcement is required, a face plate, flange, and side stiffener are welded to the bracket. The thickness of the bracket is basically determined by the girder, beam, or web plate. The thickness of the bracket is normally determined by the thickness of the web plate of the basic material. The bracket connects to the beam or column. For the bracket built-up type, a thickness adjustment and shape optimization considering the stresses are difficult. Moreover, a thicker member increases the welding requirements. Hence, a larger size and heavier member reduces the efficient use of space.

A study to change the design of the bracket girder or beam was conducted to solve these problems (Lee et al., 2004). Lee et al. attempted to omit the face bar by increasing the thickness from the standpoint of production efficiency (Lee et al., 2006). In another study, the bracket was removed from the structure, including the longitudinal stiffener or vertical stiffener (Kim et al., 2003). On the other hand, the weight of a vessel and its structure inevitably increases when a bracket is removed by strengthening the girder or beam. For a better design of the bulb bracket, a side stiffener and curve were adopted on the diagonal

Corresponding author: *Chung-Gil Kang*
e-mail: *cgkang@pusan.ac.kr*

surface line instead of the face plate. As a result, the size and weight could be reduced by 30% and 50%, respectively, using the bulb bracket fabricated in the casting process instead of the built-up type.

The authors propose a concurrent engineering solution to interconnect systematically all the processes from the material design and fabrication process design. Therefore, to produce an optimal bracket shape for an offshore structure that requires stricter weight control and efficient spatial use, it is necessary to design a low temperature, high strength, low carbon steel material for a standard bulb bracket vessel structure, instead of a built-up type. The authors evaluated the optimal structure design using the ANSYS program and designed the optimized casting process using MAGMAsoft-V5 [http://www.magmasoft.com]. The authors considered the fabrication of parts through material development, parts design, and casting process analysis of the designed parts to identify the mechanical characteristics and development method of a carbon steel bracket.

ALLOY DESIGN

Alloy design and its fabrication

The development of the raw material of the bulb bracket was carried out after setting a quantitative goal (Caron and Krauss, 1972; Offshore standard DNV-OS-B101 Metallic Materials, 2009). In the manufacturing process, low carbon scrap iron and pig iron were mixed and melted at a certain ratio. When melting reached 50%, manganese (Mn) was added initially because the melting time of Mn is longer than any other metal. After melting all the metal materials, trace minerals, such as Ni, Si, and Cr, were added based on an initial analysis Data Base (D.B) to obtain the target material. From the melted material, impurities and oxidezers were removed using a slurry remover, and deoxidization was performed using an aluminum deoxidizer as soon as melting was complete.

Preparation of alloy sample and evaluation of its chemical composition

To measure the component ratio of the alloy, a 100 *mm* thickness sample was cut and polished using a polishing machine. Five points were measured using SPECTRO MAX. Table 1 lists the average values.

The carbon equivalent is the relative ratio of the alloy element acting as carbon or playing carbon-like role in a metal material. Various equations have been applied to the carbon equivalent. In Ceq (1), the maximum value is considered up to 0.45, and up to 0.25 in Pcm (2).

$$\text{Ceq: } C+Mn/6+Si/24+Ni/40+Cr/5+Mo/4+V/14 \tag{1}$$

$$\text{Pcm: } C+Si/30+(Mn+Cu+Cr)/20+Ni/60+Mo/15+V/10+5B \tag{2}$$

The critical cooling speed and transformation temperature were lowered according to the carbon equivalent, which allowed easy transformation to martensite to increase the hardenability. Higher hardenability causes bending deformation and cracks. Therefore, bending and cracks might be avoided by preheating before welding at the interlayer temperature. Therefore, the carbon equivalent in welding serves as a barometer for determining the preheating and interlayer temperature. The Pcm and Ceq of the sample, as shown in Table 1, were confirmed to be within the allowable range.

Table 1 Chemical properties based on chemical analysis of the sample (%) (before casting).

C	Pcm	Ceq	Si	Mn	P	S	Ni	Cr	Mo	Cu
0.112	0.219	0.446	0.367	0.96	0.019	0.014	0.5	0.5	0.185	0.023

HEAT TREATMENT

Experimental set-up

Heat treatment was carried out to achieve the target mechanical properties, such as yield strength of 490 *MPa*, tensile st-