Study on the quality of FRP fishing vessel based on improved Fishbone Chart

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Abstract. The construction quality of FRP fishing vessels influences their production, use and industry development. In order to explore the factors that affect the construction quality of FRP fishing vessels, key factors affecting the construction quality of FRP fishing vessels are determined based on the quality problems of FRP fishing vessels constructed. The improved Fishbone Chart is used to analyze the eight factors of “human, machine, material, process, environment, inspection, design and information”. Taking the factors that affect the construction quality of FRP fishing vessels as the central target, the eight influencing factors were condensed into five aspects and a composite Fishbone Chart is drawn. The Fishbone Chart is used as the basic model, the influencing factors are sorted, screened and discriminated, and the system model convenient for construction site management and control is established. Finally, the causes of poor construction of FRP fishing vessels are analyzed and discussed, and relevant suggestions are put forward.

1. Introduction
FRP is a kind of composite material made of glass fiber and its products as reinforcing material and synthetic resin as matrix material. FRP has the characteristics of small relative density and high specific strength. Its advantages include shock resistance, corrosion resistance, heat insulation and electrical insulation. The FRP fishing vessel constructed with this material has beautiful appearance, smooth finish and long service life. The Chinese FRP fishing vessel began construction in 1970s, and it has undergone three ups and three falls. The service life of FRP fishing vessels can be up to 50 years. In 1985, China developed 16.88 m FRP trawler. It has a good hull form and a high level of hull structure design. Due to the imperfect construction technology, FRP fishing vessels have been scrapped in less than 10 years. During the Ninth Five Year Plan period of China, a serious defect in the design and construction of a 33 meter trawler led to abandonment. In 2004, during the operation at Fiji fishing grounds, there was a quality accident in the FRP tuna fishing vessel built by the Shandong West harbor ship repair factory. These problems have challenged the fishing community to the quality of domestic FRP fishing vessels [1-2]. Therefore, the improvement of FRP fishing vessel construction quality has become the focus of attention at the moment.

2. Improvement of Fishbone Chart analysis
Fishbone Chart, also called causal analysis chart or characteristic factor diagram, is an important method of accident analysis [3]. The factors that influence product quality is divided into human,
machine, material, process and environment by traditional Fishbone Chart. However, the quality of the products has been beyond the scope of the traditional Fishbone Chart. The improved Fishbone Chart combined the ideas of Japanese famous expert Mr. Taguchi Xuanichi about the quality of products. It will increase the original five major factors to eight major factors, namely, “human, machine, material, process, environment, inspection, design and information” (Shown in figure 1) [4].

After the improved Fishbone Chart has been applied, we can systematically and comprehensively summarize the influencing factors and put forward reasonable preventive measures. The analysis steps of improving Fishbone Chart are as follows [5]:

- Survey: a comprehensive understanding of accidents and awareness and analysis to prepare for accurate graphics.
- Fix the problem: the accident, the problem or the object of study as the "result", draw on the right hand side of the picture, and draw the trunk and arrow.
- Analyse the causes and categories: collect, analyse and list the causes, organize and classify them according to the importance and cause and effect.
- Mapping: fill in the drawings one by one.

3. Construction quality analysis of improved Fishbone Chart

3.1 Ideas for building improved Fishbone Charts
In the design and construction process of FRP fishing vessels, the design of the product quality is the first step, followed by the construction and inspection. The improved Fishbone Chart was established by combining the quality of FRP fishing vessels with the formation of the real situation and based on the concept of total quality management and source quality management. The eight factors are divided into five major areas, namely, construction personnel and environment, hull design, raw materials, construction process, inspection of FRP fishing vessel. Based on the complexity and complexity of the influencing factors, a composite Fishbone Chart of five aspects is established (Shown in figure 2).

3.2 The induction and analysis of influencing factors

3.2.1 Construction personnel and environment. At present, the moulding method of FRP fishing vessel in China is hand lay up moulding. Its mode of operation is mainly manual operation. Although the operation is simple, it requires higher operating techniques. Therefore, not only the construction staff needs to have a serious work attitude and rich experience, but also managers need to supervise and manage the work. The construction of the building capacity of shipyard should stand the test and environmental control in the workshop temperature of less than 32°C, relative humidity is not more than 85% (Shown in figure 3).
3.2.2. Hull design. Hull design can be divided into structural design, alignment design and local design. The structural design factors of FRP fishing vessels are the connection of the important nodes, the form of the frame and the choice of the plate structure. Linear design is the mother ship type selection and bilge line selection. The local design is mainly the choice of sandwich structure and the manufacture of bulbous bow (Shown in figure 4).

3.2.3. Material factors. Selection of raw materials. The choice of raw materials is mainly divided into glass fiber base material and synthetic resin. The roving is made of fiberglass from a FRP fishing vessel and can be woven into either a twist or a chopped fiber felt. Compared with short cut fiber felt, twist - free coarse gauze is not only of high strength but also of high cost. Therefore, it is necessary to combine the purposes of increasing the strength of the material and reducing the use cost. Raw material treatment is mainly glass fiber surface treatment, that is, glass fiber pretreatment. The treatment can improve the state and physical properties of the glass fiber surface. Glass fiber surface treatment methods are generally three kinds: pretreatment, post-processing, and direct blending with resin [6]. The mechanical properties, electrical properties, weather resistance and water resistance of the FRP were improved after the treatment of the surface of the glass fiber (Shown in figure 5).

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**Figure 2.** Improved Fishbone Chart of FRP fishing vessel.

**Figure 3.** Construction personnel and environmental factors Fishbone Chart.
3.2.4. Construction technology. The construction process of FRP fishing vessel consists of mold construction process and forming process. The mold construction process includes the material and structure of the mold. The construction of the mold affects its quality, ease of operation, and ease of film removal. FRP fishing vessels are relatively large products in FRP products. The appropriate mold form is selected through the construction of quantities, plant conditions, and economic benefits. FRP fishing vessels are mainly made of mold, including wooden mold and glass steel mould and the structure is composed of two parts: integral die and assembled die [7].

The forming process of FRP mold: cleaning, paint remover, spray coating, laying molding, stripping and mounting connection. In order to build a high quality FRP fishing vessel, it is necessary to strictly control every link of the molding process and formulate a strict technological process (Shown in figure 6) [8].
3.2.5. Inspection of FRP fishing vessel. Inspection of FRP fishing vessels includes inspection of material properties, inspection of mold quality and inspection of hull construction. (Shown in figure 7).

- Inspection of material properties requires the construction of resins and fiberglass reinforced materials for FRP fishing vessels to be approved by the vessel inspection division. The shipyard shall submit the material certificate and material performance test report to the inspection department. In addition, FRP fishing vessels in the production phase shall submit test reports of FRP specimens to the inspection departments.
- The mould test includes inspection during manufacture and inspection before laminating. The mould is mainly made of wood mould and FRP mould. The moisture content of wood should be controlled at 15%~20%. The FRP mould surface must adopt mould gel coat resin; the dosage should be controlled at 600~800 g/m². The surface of the mould shall be smooth and the joint shall be smooth.
• The inspection of hull construction is divided into the inspection in the process of laminating, the inspection before the membrane removal and the inspection of the two bonding. The surface should be smooth, uniform color, gel coat layer do not have wrinkles, cracks, bubbles and other defects.

3.3. Measures to improve Fishbone Chart to determine the influencing factors

Through the improvement of Fishbone Chart, the unsafe factors in the construction process of FRP fishing vessels are analyzed. Through the above analysis, we formulate measures for different factors:

• Train the construction staff to achieve the required technical level. Enterprise qualification has been certified and irregularly checked.

• The skeleton forms of FRP fishing vessels are mostly mixed skeleton structure. It is characterized by vertical and horizontal spacing is basically the same aggregate can ensure the longitudinal strength and transverse strength of fishing vessels [9-10]. The plate structure has a trapezoidal foam structure, which is subjected to greater failure stress [11]. Bilge linear selection of angle than round bilge rolling performance [12]. Choose the angle of FRP bilge not only overcome poor rigidity and do not need to install the vertical fin or increase the breadth.

• In the coating, the permeability of the fabric will affect the beauty and quality of the FRP. Therefore, the first and last layers of paste are made of fiber felt. The synthetic resin adopts unsaturated polyester resin. The advantages of these resins are good curability, easy construction and easy quality assurance [13-14]. In addition, the storage time of unsaturated polyester resin is generally half a year. During construction, the environment and storage time affect the properties and material of the resin, so the storage of the material needs to be noticed.

• The wooden die was the most widely used in the construction of FRP fishing vessels. From the point of view of accuracy and benefit, the FRP die reinforced plastic will be adopted. In combination with the economic benefits and construction quality, most of the fishing vessels are made of wooden dies and the parts with higher accuracy (such as bulb bow) is made of FRP dies.

• The fiber width is not wide, so it is necessary to Ply Splice process. The process is divided into lap joint and butt joint, which reduces the loss of the strength of FRP and guarantees the appearance quality and dimensional accuracy [6]. In the process of paste making of FRP fishing vessels, the form of lap joint is mainly adopted. This form is to stagger the joints in one direction and form a trapezoidal joint. The form of the lap joint increases the strength of the joint area and the retention ratio of the elastic modulus.

4. Analysis of the advantages and disadvantages of Fishbone Chart

4.1. Advantage

Fishbone Chart is a method of finding the root cause of the problem. It has the characteristics of intuition and simplicity [15-16]. On the one hand, Fishbone Charts can give full consideration to the influencing factors, identify symptoms, analyze the causes, and find solutions. On the other hand, by brainstorming, there is unlimited free association and discussion. The relevant risk factors are summarized and the causal relationship is clarified in an orderly and easy to read way. In addition, the method is easy to master, and can be used to guide field safety construction after short-term training.

4.2. Disadvantages

Compared with the fault tree analysis method, the fault tree can be used for quantitative analysis and systematic evaluation of the influencing factors [17-18]. According to the probability of occurrence of each factor, the probability of accident is calculated and a specific quantity concept is provided to achieve the purpose of quantifying the index of influencing factors. Compared with the method of
arrangement, arrangement is the influence degree of the factors affecting the histogram sequence, so as to find out the main factors [19]. According to the principle of "critical minority" and "secondary majority", the analysis of product quality is realized. But the Fishbone Chart is the qualitative analysis of the influencing factors and the probability of each factor cannot be accurately calculated. Fishbone Chart is a tool to break the big concept into some small concepts with motivation, which reflects the influence and logical relation among various factors. It is not convenient to establish the chain of cause and effect between each influence factor.

5. Summary and outlook
The factors that affect the construction quality of FRP fishing vessels come from every aspect. In the construction process, we need to learn from the mature design of developed countries and regions, combine the characteristics of raw materials in China, improve the construction process, reduce construction costs, and facilitate the fishermen to accept. The influencing factors were divided into 3 types: design, material and process. The different types of factors were studied from different angles, and the basic model of Fishbone Chart was established. With the advantages of simple and practical, intuitive and easy to understand, Fishbone Chart model was applied to every link of the construction process.

The structure design, raw material and molding process of FRP fishing vessel interact with each other, but Fishbone Chart is not convenient to establish the chain of three aspects. The basic model of Fishbone Chart should be weighted and arranged according to the time sequence. The logical relationship between the factors is found, and the structure analysis chart is built. Finally, the perfect basic model is built and the relevant database is built. Through further practice, the applicability of this method in the construction of FRP fishing vessels is studied, and the model is more truly reflected in the construction process of FRP fishing vessels.

Reference
[1] Zhao S P, Wang W Y, and Yao L 2013 J. Chinese Fisheries Economics 31 28-47
[2] Zheng J L and Gao C 2016 J. Chinese Fisheries Economics 34 42-47
[3] Chen J M and Wen R S 2009 J. Shanxi Architecture 35 40-41
[4] Wang J L Discussion about “Fishbone Chart” Improvement J. Standard Science JHEP02 (2010)
[5] Wang S P 2011 J. Safety in Coal Mines 42 113-116
[6] National Building Materials Bureau Shanghai FRP Research Institute 1984 FRP hand lay up molding (Beijing: China Building Industry Press)
[7] Takashi F, Kasahara K and Kanayama Y 1989 FRP Fishing vessel (Dalian: Dalian University of Technology Press)
[8] Zhang W G 2001 Research Report on construction technology of FRP fishing vessel J. Fiber Composites JHEP02 (2001)
[9] Qiu J X 2007 J. China Water Transport 5 8-9
[10] Song X F Wan R and Gao Q L 2003 Study on FRP fishing vessel connection technology J. Shandong Fisheries JHEP03 (2003)
[11] Qiu T X and Li X M 2000 J. Ocean University of China 30 62-67
[12] Qiu T X, Li W T, Song X F and Gao Q L 2000 J. Journal of Fishery Sciences of China 7 87-90
[13] Chinese Society for corrosion and protection 1995 Synthetic Resin and FRP (Beijing: Chemical Industry Press)
[14] Zheng Z C, Li Y Z and Tang Y 2008 J. Sichuan Architecture 28 183-186
[15] Wang J Y 2011 J. Liaoning Chemical Industry 40 1270-1271
[16] Deng X W, Chen Q H and Jiang D X 2013 J. Guangdong Electric Power 26 73-77
[17] Hao C X, Xu Y and Gong S W 2012 J. Journal of Safety Science and Technology 8 154-159
[18] Yang H X and Sun Y X 2011 J. Journal of Safety Science and Technology 7 203-206
[19] Liu Z, Nie X T, Wu S S and Gao J Y 2016 J. Shanxi Architecture 42 229-230