Special lifting and transport solutions for heavy and complex loads in the design of the lifting frame

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Abstract. Approach and reasoning for developing new solutions and lifting methods, effectively manage risk. This comes in various forms, primarily reducing risk to staff and secondary, reducing or eliminating risk to plants and customers. This is why front-loading engineering solutions are being developed that provide improved safety, schedule improvement and cost efficiency. The paper presents solutions for lifting and transport systems in which alternative methods are used.

1 Introduction

Cranes, in the modern sense, are lifting installations usually composed of a metal frame, of variable shape, construction and size, and of mechanisms necessary to lift and move loads. Cranes can be classified according to various criteria, taking into account the mode of operation and the construction type: fixed or movable, movable on its own track or on an independent track, self-propelled or towed, etc.

Very often, the area of activity of cranes coincides with the area of people's activity, potentially endangering their safety and life. There are not few cases when accidents due to cranes have resulted in loss of human life and significant material losses. Another important criterion is the one related to the load to be lifted and transported.

The paper presents some solutions for heavy and complex loads.[1]

2 The future of heavy duty lifting and lifting solutions

An approach to lifting and lifting solutions for heavy and complex loads mainly involves cranes with some special equipment or must be modified to comply with the requirements of a typical project. For the realization of these special cranes, special modular solutions and systems have been developed aimed at the load to be transported and lifted, which are meant to satisfy the needs of a given project. The special system solutions are designed in the form of modular systems, thus making it possible for future use.

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The special modular systems have as their essential characteristic Safety, which is followed from their design phase, representing an alternative to the conventional solutions for the crane and the hydraulic bridge. Modular systems are a new approach to specialized lifting systems and hardware equipment and allow the creation of flexible rigid equipment through modular construction.

The modular construction ensures a decrease in costs with safety, the installation and implementation of special systems. Constructive solutions based on modules for the realization of lifting and transporting systems are applied for heavy and complex tasks in special installation conditions [1].

3 Modular construction solution of a lifting and transporting system

The modular construction of the lifting and transporting system presented is designed for the installation of fans in a hall of a nuclear power plant without dismantling the ceiling of the hall and without requiring the dismantling of the existing wiring on the ceiling. [1, 2]

The challenge is to mount the fan installation beam that it is very close to the floor of the room, respectively at a height of 92 m compared to the height of the ceiling of 96 m.

The classic solution with existing classic cranes is impossible because the difference between the elevator beam and the ceiling is 4m

The proposed solution was to design a lifting frame that would take the fans from the bottom of their frame and raise them within the enclosure to the desired height thus eliminating the limitations of the room.

When designing the lifting frame, the following assumptions were taken into account:
- o The lifting frame will be used for the limited duration of the installation of the fans, resulting in a low number of operational cycles (<< 20,000). Therefore, extended use and fatigue are not taken into account.
- o Given the limited time, the equipment will be installed in less than 90 days - the lifting frame and the corresponding equipment will work temporarily. Therefore, seismic loads are not taken into account. It is assumed that the beams are installed indoors and are not subject to environmental loads - e.g. snow, wind, etc.
- o The track beams will be installed on an existing steel frame at an elevation of 822'-10" of the NPP, between Column Lines D through F, in the east-west direction, and parallel to Column Lines 2 through 5, in the direction north-south. The bottom flange of the runway girders will be fixed to the top flange of the girders at that elevation. The assessment of the existing support structure is outside the scope of this document.
- o The primary, load-bearing components of the lifting system are made of steel. Therefore, the supplied components are designed and manufactured based on the existing normative requirements for steel construction. Sizing and flexible design of track girders is based on reference guidance [3] and end plate design is based on reference guidance [4]. The preferred design approach uses Allowable Stress Design [5]; however, the approach to some components / connections is evaluated more thoroughly using LRFD.
- o The lifting frame shall utilize four (4) synchronized electronic lifts, each with a minimum capacity of 9,6803.885 kg (15,000 lbs). Each lifting cable shall be installed in a two-part configuration creating a maximum load of (13607.77 kg.(30,000 lbs) at each lifting point [1].
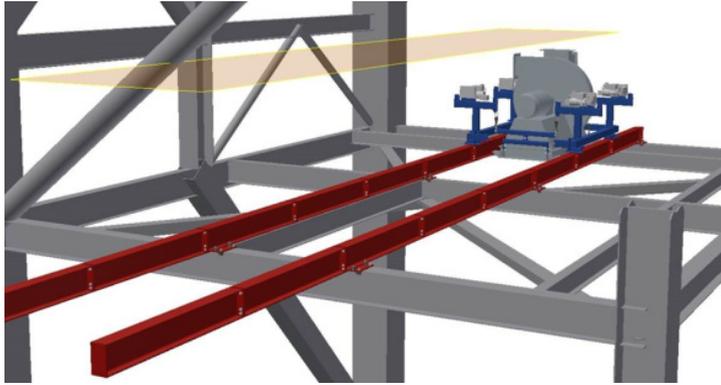
The lifting frame is shown in fig.1.

Fig. 1. Hoisting system.

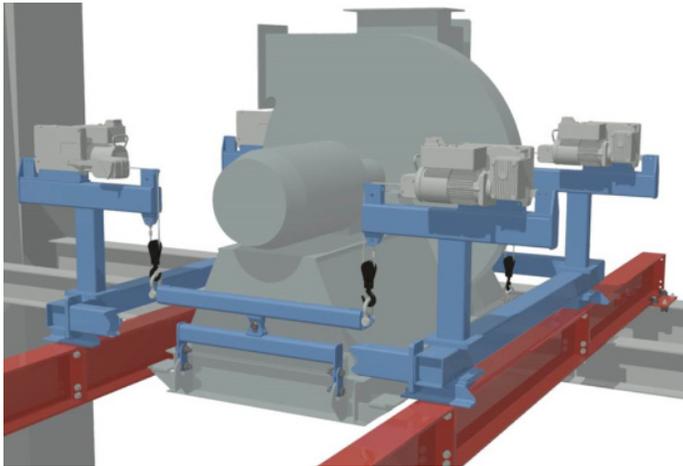The 2D front view of the lifting frame with fan is shown in fig. 2.

Fig. 2. Front view in 2D of the lifting frame with fan.

The 3D drawing of the lifting frame with the mounted fan, rear view, is shown in figure 3
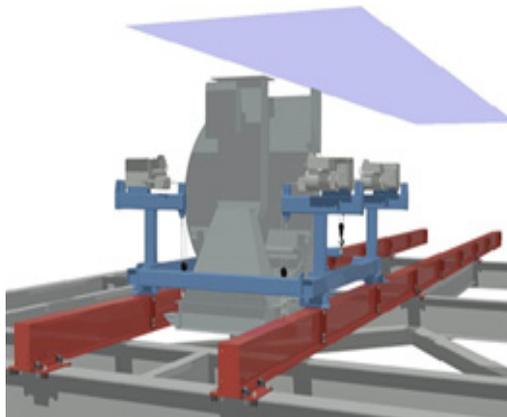

Fig. 3. 3D drawing of the lifting frame with the fan mounted, rear view.

For the design of the lifting frame, it was necessary to calculate the critical components according to the drawing in fig.4.
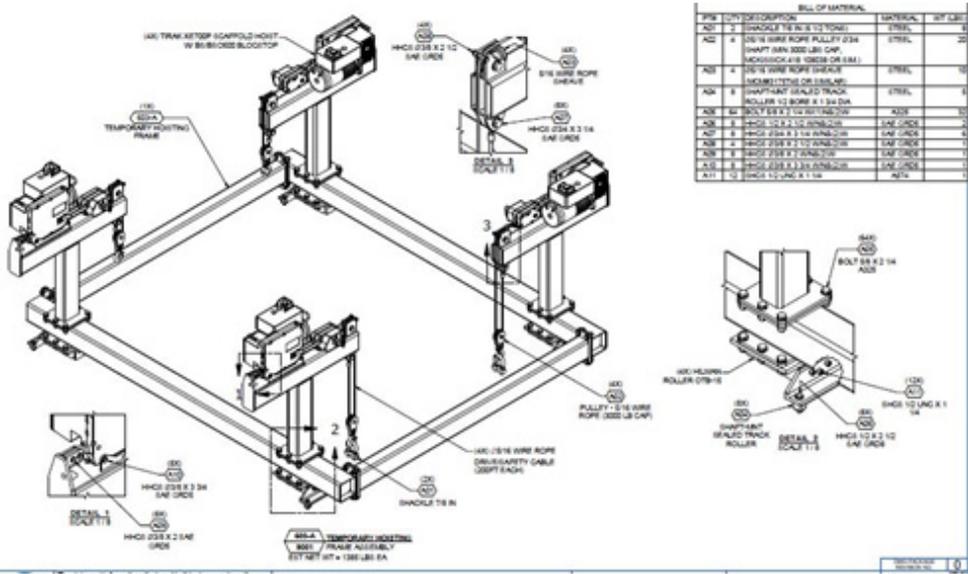

Fig. 4. Assembly details of temporary hoisting frame.

The calculation details were carried out in a calculation program and are presented in the figures 5-8:

Applied load at pin hole:
Pin load at each lug,

$$P_{pin} := \frac{P_{cable}}{2}$$

$$P_{pin} = 4.18 \, kN/m^2$$

Design Factor - Yield & Buckling, $\quad N_d = 2.0$

End lug thickness, $\qquad t_{lug} = 9.52*10^{-2} \, m$

Distance between hole C.L. and plane edge, $\quad R = 3.17*10^{-2} \, m$

Radius of lug at pin hole, $\qquad r = R = 3.17*10^{-2} \, m$

Diameter of pin, $\qquad D_p = 1.9*10^{-2} \, m$

Diameter of hole, $\qquad D_h = 1.98*10^{-2} \, m$

Edge distance perpendicular to load, $\quad b_e = r = 3.17*10^{-2} \, m$

Pin diameter to pin hole factor,

$$C_r := if\left(\frac{D_h}{D_p} < 0.90, 1 - 0.275 \cdot \sqrt{1 - \frac{D_p^2}{D_h^2}}, 1\right)$$

$$C_r = 1$$

Effective edge distance perpendicular to applied load, [2]

$$b_{eff} := min\left(4 \, t_{lug}, b_e \cdot 0.6 \, \frac{F_{uPlate}}{F_{yPlate}} \cdot \sqrt{\frac{D_h}{b_e}}, b_e\right);$$
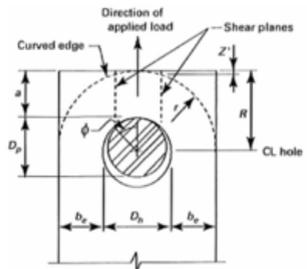
$$b_{eff} = 1.95*10^{-2} \, m$$

Fig. 5. Calculation sequence for check dead end lug pin connection.

Dist. between hole and edge,

$$a_{hole} := R - \frac{D_h}{2}$$

$$a_{hole} = 2.18*10^{-2}\,m$$

Pin contact angle,

$$\phi_{p\_h} := \left(55 \frac{D_p}{D_h}\right) deg = 52.80\ deg$$

Shear distance reduction at curved edge,

$$Z' := r - \sqrt{r^2 - \left(\frac{D_p}{2} \cdot \sin\left(\phi_{p\_h}\right)\right)^2}$$

$$Z' = 1.01*10^{-3}\,m$$

Shear plane length at pin hole,

$$Z := a_{hole} + \frac{D_p}{2} \cdot \left(1 - \cos\left(\phi_{p\_h}\right)\right) - Z' = 0.97\ in$$

(based upon

$$Z = 2.46*10^{-2}\,m$$

Shear area at pin hole, $\qquad A_v = 2\,Z \cdot t_{lug} = 4.7*10^{-4}\,m$

Fig. 6. Calculation sequence for check dead end lug pin connection.

Check End Lug Weld

Number of weld groups, $\qquad n_{weld} = 2$

Weld length, $\qquad l_{weld} = 8.5*10^{-2}\,m$

Weld nominal size, $\qquad w_{lug} = 0.188\ in$

Fillet weld effective throat, $\qquad a_w = n_{weld} \cdot 0.7071 \cdot w_{lug} = 6.85*10^{-3}\,m$

Weld group width, $\qquad b_w = l_{weld} = 8.5*10^{-2}\,m$

Weld group depth, $\qquad d_w = 15.24*10^{-2}\,m$

Weld area,

$$A_w := \left(2 \cdot b_w\right) \cdot a_w$$

$$A_w = 13.10^{-4}\,m^{-2}$$

Weld polar moment of inertia,

$$J := \frac{b_w}{6} \cdot \left(b_w^2 + 3\,d_w^2\right) \cdot a_w$$
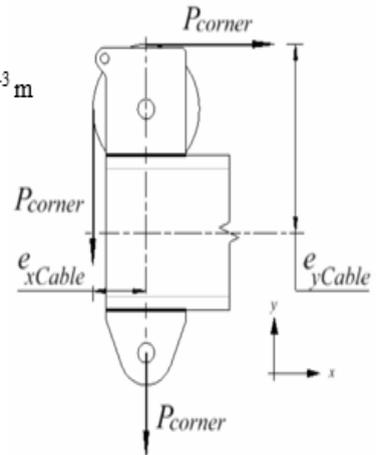
$$J = 8.45*10^{-6}\,m^{-4}$$

Fig. 7. Calculation sequence for check end lug weld.

Fiber distance to x-axis,

$$c_x := \frac{d_w}{2}$$

$C_x = 7.62 * 10^{-2}\,m$

Fiber distance to y-axis,

$$c_y := \frac{b_w}{2}$$

$C_y = 4.77 * 10^{-2}\,m$

Weld force in x-direction, $P_x = P_{cable} = 8451.58\ N/m^2$

Weld force in y-direction, $P_y = n_{part} \cdot P_{cable} = 16903.16\ N/m^2$

Cable offset in x-direction, $e_{xCable} = 6.35 * 10^{-2}\,m$

Cable offset in y-direction, $e_{yCable} = 18.41 * 10^{-2}\,m$

Torque applied to weld, $M_z = P_{cable} \cdot (e_{yCable} - e_{xCable}) = 39588.98\ N/m^2$

Weld stress in x-direction,

$$f_{vx} := \frac{P_x}{A_w}$$

$f_{vx} = 6480.92\ kN/m^2$

Fig. 8. Calculation sequence for check end lug weld.

Based on the calculations performed herein, the Temporary Hoisting Frame has a positive design margin for all members and components for all applicable load combinations and Standard Configuration for SPMT Transport [1].

4 Conclusions

Using innovative design and strong engineering in the planning phase allowed us to develop a specialized lifting frame that made it possible to install the fans in a space-constrained location without requiring changes to the existing space

The presented solution allows complex works to be carried out in limited spaces in safe and financially stable conditions

Based on the calculations performed herein, the Temporary Hoisting Frame has a positive design margin for all members and components for all applicable load combinations and Standard Configuration for SPMT Transport.

References

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