Design and Analysis of an Automated Ladle Transport Vehicle

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Abstract— Automation of industrial processes is very essential to stand them in today's competitive world. In the current work, a low cost automation system is designed for a manual industrial process. To transport the ladle containing molten metal into the respective molding boxes, an automated ladle transport vehicle is designed. In a preferred embodiment this improved automated ladle transfer vehicle comprises of a car body supported upon a structure frame, a hydraulic tilting mechanism, and the entire assembly is placed on a base frame. The assembly is provided with a wheel track arrangement, to travel from the furnace point up to the molding boxes. In order to balance the centre of mass, an arrangement of up-stop wheels is provided under the rails. The detail of design is described in this paper.

Key words: Automation, Hydraulic Supporting Frame

I. INTRODUCTION

The following design and analysis is being carried out for a foundry industry which generally uses a crane arrangement for executing the process of transporting the molten metal.
This process usually involves:

- Heating the metals in the range of 1450-1500 degrees Centigrade in the furnace and then pouring the same into the ladle.
- Transporting this ladle, using an overhead crane, from the furnace point up to the molding boxes, for pouring the molten metal.
- Ultimately pouring this hot metal alloy into the molding boxes using the manual drive tilting mechanism, usually available on the ladle.

Thus, the main aim of this design is to replace the overhead crane mechanism with an improved automated Ladle Transport Vehicle (ALTV) which would bring about significant changes in this process through automation. The many advantages of this ladle transport car will become more apparent from the following detailed description of the car and the attached figure 1.

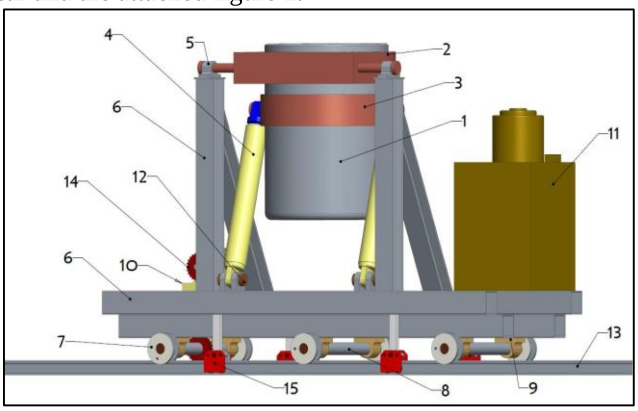

Fig. 1: Automated Ladle Transport Vehicle (ATLV)

In fig 1,

1) The ALTV includes the ladle (1), which will contain the molten metal, Poured into it from the furnace. It is made up of steel and has a coating of firebrick from inside.
2) It is supported by the Main Supporting frame (6). It is a I-shaped structure of hardened steel, Specially meant to endure higher loads, during the motion of the assembly.
3) The tilting of the ladle into the moulding boxes is accomplished with the help of a hydraulic mechanism(4), comprising of two single acting hydraulic cylinders and this arrangement being connected with the help of Intermediate (3) and the Hydraulic(4) Supporting frame.
4) A Hydraulic Power-pack (11) arrangement is provided, adjacent to the main carriage, to ensure the smooth functioning of the hydraulic system.
5) This entire assembly is mounted on the Base frame (6), again made up of hardened steel.
6) The transportation of this assembly is made possible with the help of the Wheel and Track arrangement (7,13). A total of 6 wheels are provided with 3 wheels on each side.
7) An electric motor (10) is also provided, adjacent to the main carriage. Use of chain drive and gear box can be made possible, by including them in the assembly according to the corresponding application and use.
8) The use of Up-stop(15) wheels can also be done, if there is a need for dynamic balancing of the assembly

II. DESIGN OF COMPONENTS

A. *Selection of Hinge Point and Pivot Point*

A pivot point is the centre of any rotation system or it's a pin about which a component turns or balances.
The selection of these points is done on the basis of:

1) Having uniform and confined pouring.
2) Optimum force required to bring about the tilting motion and normal extension of the hydraulic arm.
3) Maintaining clearance and avoiding interference between the hydraulic arm and the structure. After studying all the cases, the best solution was to choose the pivot point in the middle of the ladle which would provide us the optimum pressure and arm extension. Thus, the point 2, was selected, as the final pivot point.

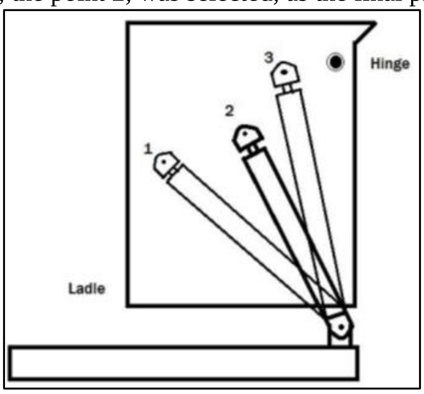

Fig. 2: Selection of hinge point

B. Design of the Main Supporting Frame

For the design of the supporting frame, an I shaped structure of hardened steel has been selected taking into consideration the following advantages: (The same has also been analyzed using ANSYS by considering pseudo loading and spatial constraints)

1) To resist High Moment, the Moment of Inertia (MI) should be high which is possible to be achieved by distribution of more material away from the neutral axis and for a given quantity of material this can be achieved in the most economic design.
2) In I section, flanges resist the bending moment and web resists the shear.
3) Also it is found to be symmetrical about both the axes and its shear centre coincides with the CG and hence the development of torsion is prevented.

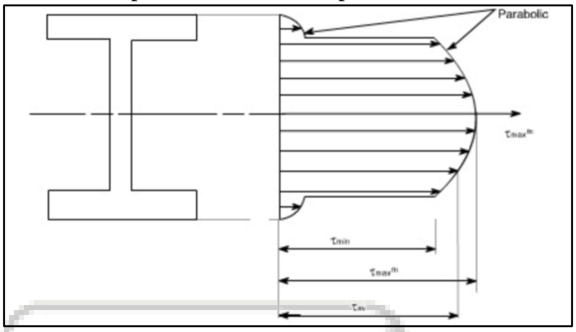

Fig. 3: distribution for I section

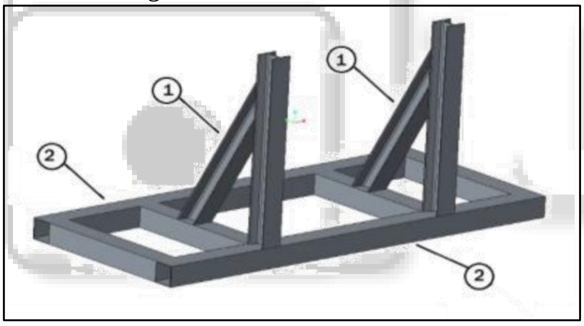

Fig 3: Main supporting frame

C. Selection of Wheel and Track Arrangement

There are many different types of wheels which can be used for this application. But, after a lot of consideration, a double flanged steel rail wheel was found to be the most suitable for this particular application, owing to the following reasons:

Flanged metal wheels for carts are vital to heavy industry as many are designed to support greater loads than other wheel types. Flanged wheels are also of great benefit in production lines where vehicles and transfer carts need to keep rolling safely and steadily with minimal effort or guidance.

In this case, with materials or equipment passing back and forth on the track, accurate tracking is a necessity. When an application requires accurate tracking, double-flanged wheels are the more desirable option because they help to lock vehicles in a fixed position on the rails. While employed for many of the same uses as single-flanged wheels, double flanged models offer an extra layer of protection from mishaps in some applications due to the added guidance they provide. A double-flanged wheel helps to guide equipment along rails accurately, with less side to side motion than may be experienced with single flanged wheels.

This, removes the need of attaching guide wheels, to the side of the rail. However, in order to maintain the dynamic balancing of the assembly, a special arrangement of up-stop wheels has been made, which will ensure the safety of the Ladle Transfer Vehicle, and also rules out the need to attach dead weight or similar arrangements to bring about the dynamic balancing of the vehicle. They are mostly used in roller coasters, to prevent it from coming off the track. Similar application of the up-stop wheels was found in this project, and was thus, implemented for tackling the issue of dynamic balancing

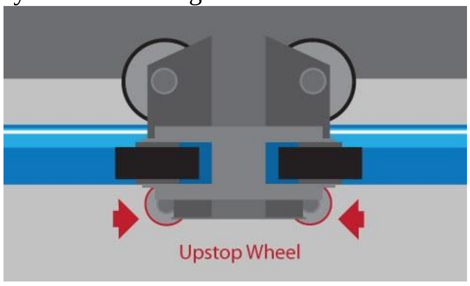

Fig. 5: Up stop wheel

III. ANALYSIS

This design was implemented and analyzed, by applying it on a real time basis to a small scale Foundry industry, where various physical constraints were recorded and corresponding values were derived for each and every component. A brief idea about the same has been demonstrated below:

A. Process Constraints

1) Total load (ladle + molten metal) = 2 tonnes (approx.)
2) Tilting angle = 95-100 degrees perpendicular to the direction of travel.
3) Distance of travel = 10 metres.
4) Speed of travel = 10 metres/min.
5) Pouring time from ladle to the moulding boxes = 30 seconds.
6) Ladle material = Mild steel with firebricks lining and asbestos sheet.

B. Selection of Hydraulic Arrangement

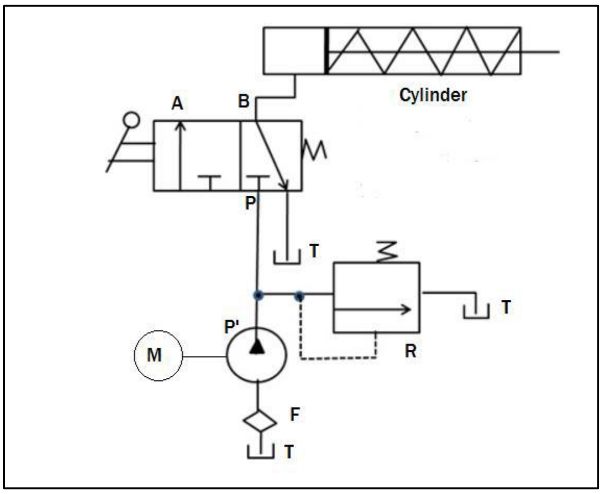

Fig. 6: Hydraulic circuit

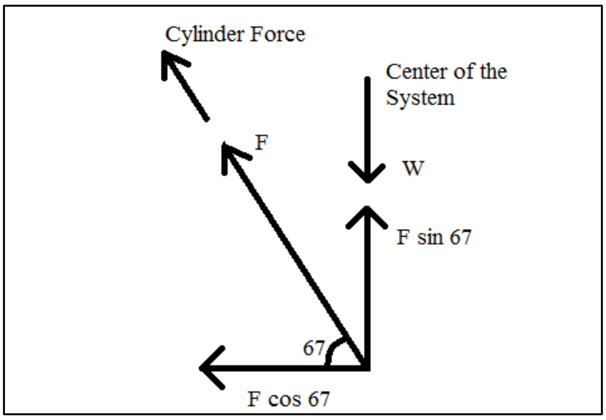

Fig. 7: Weight balancing

For a cylinder with a standard diameter of 4 inches i.e. 10.16 cm and FOS = 2, the total force calculated comes out to be 41.94 kN. As the circuit contains 2 cylinders; total force on each cylinder comes out to be 21.31 kN. The pressure on each cylinder is 26.29 bars. Using the above calculated values, discharge of the pump is found out to be 189.17 cc/sec. Hence the effective discharge for 2 cylinders is 378.34 cc/sec. And the speed of the forward stroke of the piston is 2.33 cm/sec. Hydraulic components such as Clevis Brg, Hydraulic Power pack, Gear Pump, are used in bringing these optimum values. After taking into account all the spatial and loading constraints, the final assembly along with its corresponding dimensions is shown in fig 8 :

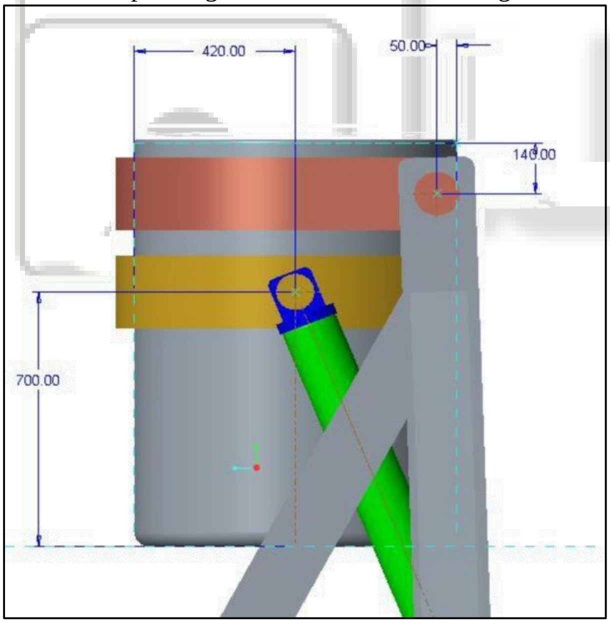

Fig. 8: Final Assembly

Similar approach can be followed for deriving the specifications for the above design, corresponding to the respective constraints.

IV. CONCLUSION

The main aim of this design is to replace the crane mechanism with an Automated Ladle Transport Vehicle (ALTV) which would help the organization in the following ways: Increased production rates and process optimization. Reduction in the number of labors required during the process i.e. from six to eight presently to only one for inspection purpose.

Savior of the labors from the harmful gases evolving during the present manual tilting process.

The above changes require the modification in the material handling system and an additional rail wheel arrangement needs to be incorporated in the area adjacent to the furnace and molding boxes.

REFERENCES

[1] Prajakta Bawiskar, Sachin Kamble, Kiran Bhole/ Design of Tilting Ladle Transfer Car for Steel Industries/ World Journal of Science and Technology/ ISSN: 2231-2587/ April 21, 2012, 2(4):20-23
[2] V. N. Artyushov, D. V. Akhmetov, O. K. Tokovoi, V. S. Baldin, K. V. Vol'skii/ Pumping slag from a hot-metal-car ladle before the pig iron is poured into a converter/ Metallurgist July 2009, Volume 53, Issue 7-8, pp 404-407.
[3] Yoshiyuki Noda, Tadashi Nishida/ Precision Analysis of Automatic Pouring Machines for the Casting Industry/ Toyohashi University of Technology/ April 30, 2008.
[4] Griffiths Clyde/ Foundry ladle transfer car/ US2889597/ Whiting Corp/ Jun 9, 1959.
[5] Britcher Harry, Gallucci Francis/ Car having ladle supporting and positioning means/ US3459312/ United States Steel Corp/ Aug 5, 1969.
[6] Morhart Karl, Spannlang Ronald/ Converter-carrying transfer and positioning vehicle/ US3593859/ Voest Ag/ Jul 20, 1971.
[7] Jon L.Stimpson/ Weight measurement system for steel mill transfer cars/ US7241956/ Stimpson Jon L/ Jul 10, 2007.