Hydraulic Manipulator of Injection Molds for Die Casting Design

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Abstract. This paper contains a search of the issue of handling and handling jigs in the field of die casting of aluminum alloys. The paper deals with the design of a hydraulic manipulator of injection molds for pressure casting of aluminum alloys. Several basic variants of a possible solution have been proposed for the positioning of casting molds. From the proposed variants, the best suitable solution was selected; it is structurally designed in more detail and subjected to control calculations.

Keywords: Construction · Design · Manipulator · Injection Mold · Positioner

1 Introduction

The manipulator is used for rotational positioning of the casting molds from the horizontal to vertical position and vice versa. The range of movement of the manipulator is 90°. When positioning the mold, it must be rigidly and securely clamped to the rotating part of the manipulator. In both extreme positions, there must be access to all required parts of the mold with regard to ergonomics for the needs of mounting additional components on the mold or for the needs of its service.

Molds positioned on the manipulator are used for pressure casting of aluminum alloy for the production of engine blocks. The molds are transported from the tool room department to the aluminum foundry hall on the truck in a horizontal position. With the help of a bridge crane, the mold from the car is folded onto the floor surface. The mold needs to be inserted into the aluminum alloy pressure injection machine in a vertical position. The mold is used in the machine for the production of blocks of a certain type of internal combustion engine of passenger cars. The mold remains in operation in the casting machine until the required number of pieces of the given type is produced; or until failure. Then the mold is removed from the machine in a vertical position. It is, therefore, necessary to position the mold from a horizontal position to a vertical one for subsequent placement in a casting machine or in a storage stand. And conversely, the mold must be turned from a vertical to a horizontal position for the subsequent removal of the mold maintenance or repair to the department tool shop.

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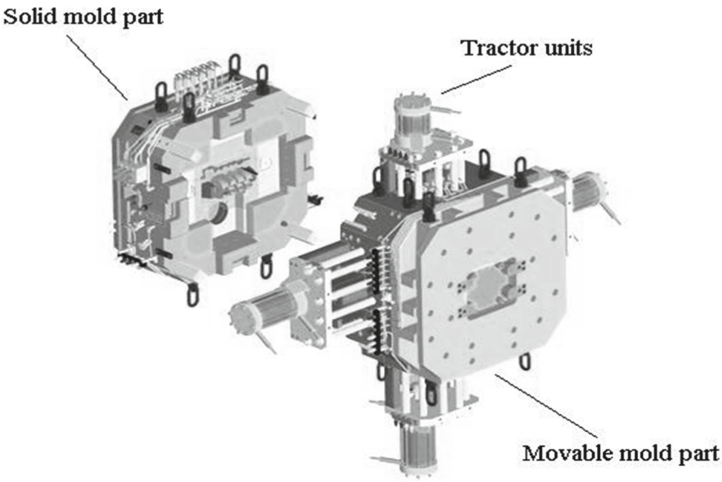

Fig. 1. Mold for die casting of internal combustion engine blocks. [3]

1.1 High-Pressure Casting

High-pressure casting is a specific type of casting, which allows, above all, high precision of casting, fabrication and weak wall thicknesses and complex shapes. It is used for casting non-ferrous metals, especially for aluminum alloys.

The cavity of the casting mold indicates the shape and surface quality of the casting. Inserted cores are also used to create the desired shape. The die (see Fig. 1) consists of a solid part into which molten metal is fed under pressure. [1–3] Furthermore, consist of a moving part, which is closed and fixed during casting and solidification. After the casting has solidified, the moving part of the mold separates in the machine to allow the finished casting to be removed. The mold is also equipped with tractors that are used to pull the cores. The casting is removed by means of a robotic arm. Before the next casting, the condition of the mold is automatically checked, a non-stick spray is applied and cast iron inserts are inserted by the robotic arm, which are cast into the casting. The moving part of the mold is moved to the fixed part of the mold and firmly closed.

1.2 Motivation for Designing a New Manipulator of Injection Molds for Die Casting

The newly designed manipulator is to replace the current manually rotating mechanical tipper, which is tilted by a lever mechanism using a crane. The current tipper is equipped with manually tightened mold clamps, which are tightened using very large side wrenches. The existing tipper is dimensioned for the already insufficient 25 t.

Certain types of possible variants of positioned molds with clearly given dimensional and mass parameters were entered. Significant parameters were the external dimensions of the mold, the size of the base, weight and location of the center of gravity. Due to the low frequency of use, the speed of positioning does not play a significant role. The positioning speed is thus adapted to the safety and economic costs per drive unit.

2 Materials and Methods

2.1 Hydraulic Manipulator of Injection Molds for Die Casting Design

Three concepts of design solution of manipulator of injection molds for die casting were proposed: [4, 5].

- Hydraulic manipulator of tipping type;
- Manipulator with electric drive of cradle type;
- Cradle-type hydraulic manipulator.

After evaluating all the advantages and disadvantages, the third variant of design solution was chosen.

The third proposal (see Fig. 2 and Fig. 3) combines the advantages of the two previous variants. It is, therefore, a manipulator with side stands with a rotary table of the cradle type located between the stands. Installation and ergonomic options are therefore advantageous. The center of gravity of the rotating masses is approached as close as possible to the axis of rotation of the positioning. Thus, a relatively small torque is required to perform the positioning. The drive is solved by two linear hydraulic motors. The translational motion of these motors is converted to rotary motion by lever mechanisms. This entire drive mechanism is located inside the side support stands of the manipulator. The same hydraulic unit is preferably used for the drive, which also serves for hydraulic clamping of the mold.

The selected most advantageous variant, together with the adaptation of the entire workplace, was modified several times and technically consulted with the customer at several meetings. The final version was technically approved by the customer, and a detailed design of the manipulator followed.

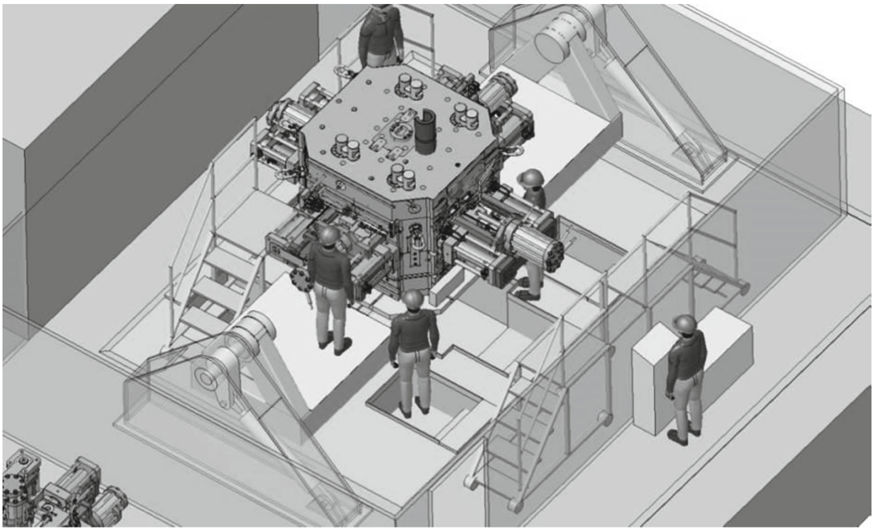

Fig. 2. Cradle-type hydraulic manipulator in a horizontal position. [1]

3D model of the manipulator was created using Solidworks software. The total weight and the location of the total center of gravity of the rotated masses with respect to the axis of rotation in the horizontal position of the manipulator were analyzed using 3D Solidworks software too.

Design calculations and strength check calculations were performed analytically, and also for selected parts were performed using computational MITCalc software. [6, 7] Stress and strain analyses by the FEM method using Abaqus software were performed for main structural supporting parts (see Fig. 4, Fig. 5 and Fig. 6).

To enable safe operation of the manipulator, the control system must have a sufficient number of current status signals.

The manipulator is equipped with the following sensors for safe control:

- Tilt sensors;

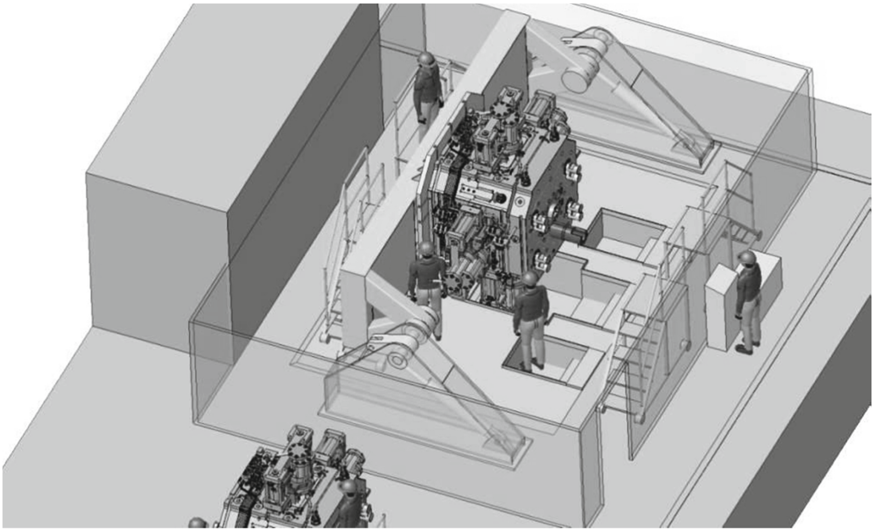

Fig. 3. Cradle-type hydraulic manipulator in a vertical position. [1]

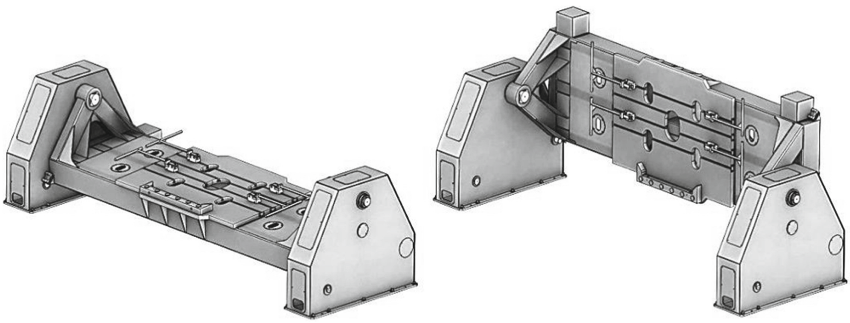

Fig. 4. Main structural supporting parts of the hydraulic manipulator - two stands and tilting table. [1]

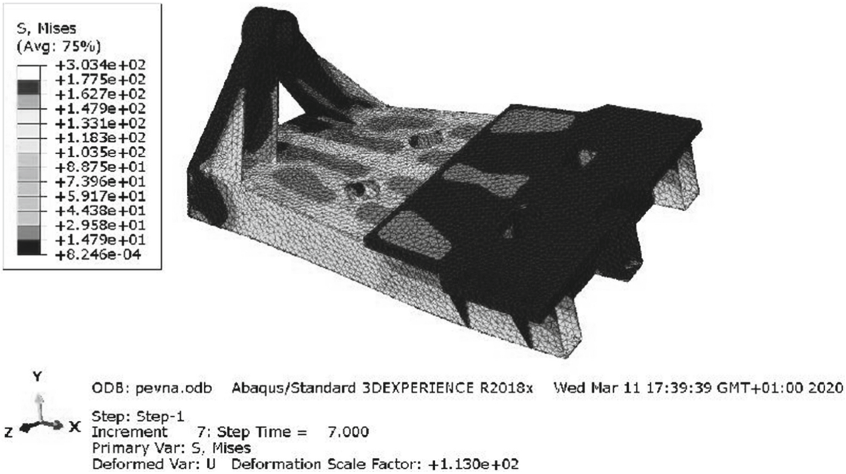

Fig. 5. Tilting table of the hydraulic manipulator – stress analysis by the FEM method using Abaqus software (for a tilt angle of 90°). [1]

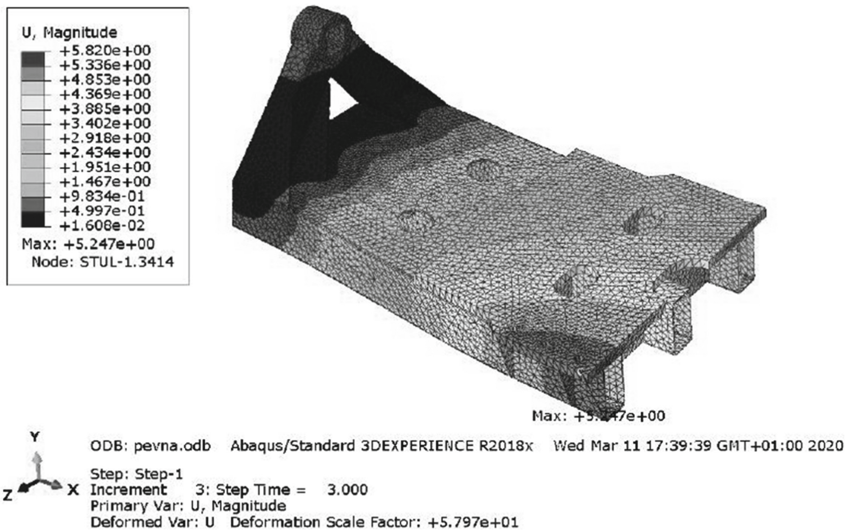

Fig. 6. Tilting table of the hydraulic manipulator – strain analysis by the FEM method using Abaqus software (for a tilt angle of 30°). [1]

- Sensors for the correct position of hydraulic clamps;
- Optical mold clamping sensor;
- Pressure sensors in the hydraulic system;
- Sensors of the position of insertion and extension of the locking pins;

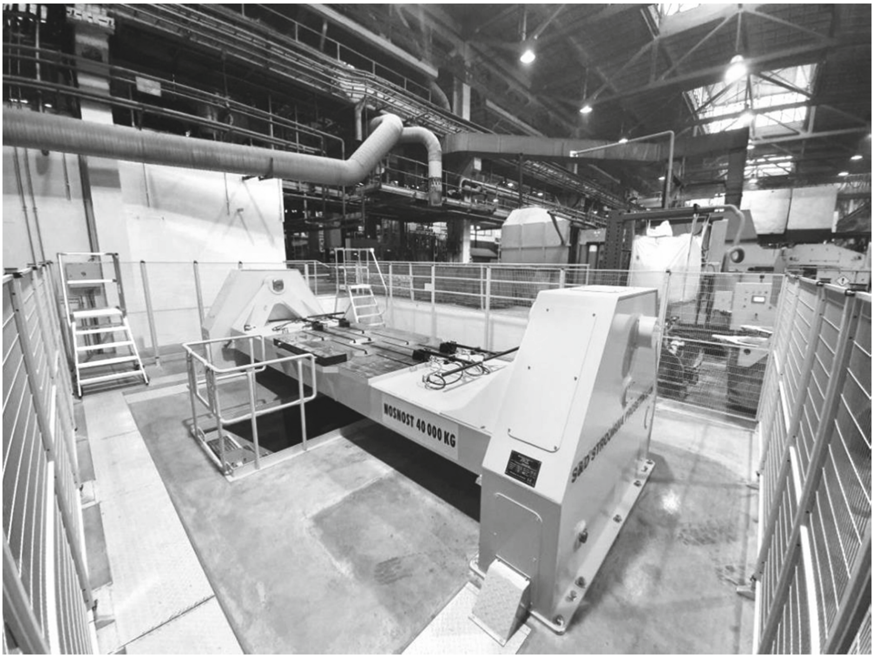

Fig. 7. Workplace of the hydraulic manipulator. [1]

- Closed fencing gate sensor.

The hydraulic drive generates the necessary forces that act on the lever to ensure the required torque on the shaft and set the rotary table in motion, or to keep it in any tilted position. The hydraulic motor was chosen with regard to the required forces, strokes, simplicity of design and price. A simple linear double-acting hydraulic motor CDL2MP5/125/80/700D10/B11CFU from Bosch Rexroth was selected.

The workplace of the manipulator is fenced with a security modular fencing with a gate (see Fig. 7). Inside the fenced workplace, there are two mobile platforms, which serve for easy access to the required places of the casting mold during the work of the workplace operator. The hydraulic unit and the control panel are located outside the fencing. The control panel has an electrical switchboard and a counter with control buttons, and a PLC programmable logic controller with a touch screen, which is a visualization of all the necessary information about the status of the manipulator (see Fig. 8).

2.2 Hydraulic Manipulator of Injection Molds for Die Casting Manufacturing and Testing

Complete production of the manipulator was provided in the company S&D STROJÍRNA PROSETÍN s.r.o., which has extensive experience in the production of heavy and large steel weldments, including their machining.

The weldments of the main supporting parts were manually welded using the MAG method. Large welds were machined on a horizontal boring machine (see Fig. 9).

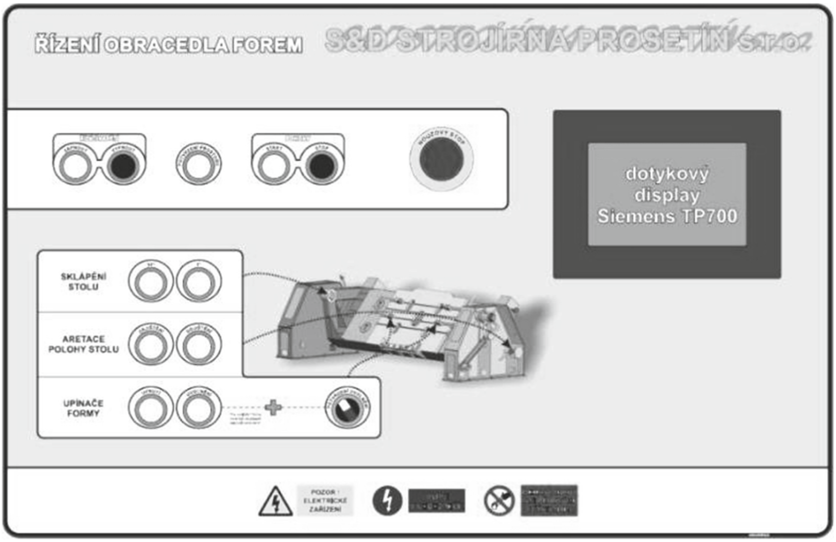

Fig. 8. Control panel of the hydraulic manipulator. [1]

Smaller parts were machined on conventional or CNC milling machines and lathes. Holes that did not require precision and correlation to machined surfaces were made on a column drill. Finally, the parts were painted and assembled. Later, hydraulic and control elements were installed.

The hydraulic manipulator of injection molds for die casting has been completely tested for proper function before delivery to the customer (see Fig. 10).

3 Results and Discussion

The designed hydraulic manipulator of injection molds for die casting achieves these technical parameters: [1, 8–13].

- Maximum weight of injection mold for die casting: 40 000 kg;
- Total weight of hydraulic manipulator: 11 072 kg;
- Maximum dimensions of manipulator [in mm]: L 7 344/W 2 400/H1 939;
- Range of working position of the tilting table: from 0 to 90°;
- Maximum force on the piston rod of the hydraulic motor: 165,5 kN;
- Cylinder diameter of the hydraulic motor: 125 mm;
- Piston rod diameter of the hydraulic motor: 80 mm;
- Stroke of the hydraulic motor: 700 mm;
- Working pressure in the engine for the required force: 13,5 MPa;
- Maximum hydraulic oil pressure: 25 MPa.

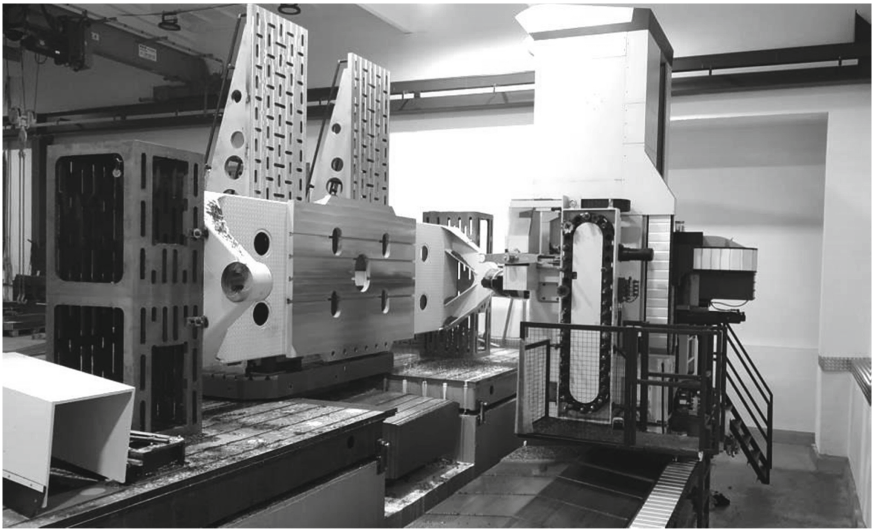

Fig. 9. Machining of the tilting table of the manipulator on a CNC horizontal boring machine. [1]

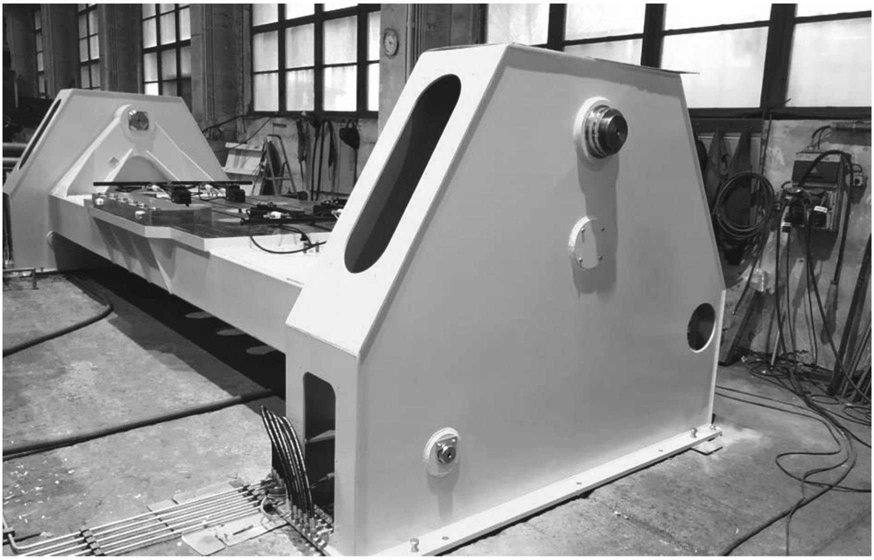

Fig. 10. Assembled manipulator when testing functionality. [1]

4 Conclusion

The designed manipulator of injection molds for die casting fully meets the specified requirements. The manipulator is suitable both in terms of strength and in terms of permissible deformations, service life, usability, economy and, above all, safety.

Molds weighing up to 40 t will be placed on the manipulator. When handling such heavy loads, there are always some risks that have been suppressed by using various safety elements and measures to the lowest possible limit. The operation of this device requires a properly trained operator.

From an economic point of view, this device excels in relatively low production costs and thus in the purchase price. Another indisputable advantage is, above all, very low operating costs, maintenance and service costs.

The manipulator was also designed with regard to transport to the customer. It was, therefore, possible to load the manipulator into a standard truck in a completely assembled state and take it to the customer. This significantly simplified the final assembly at the customer.

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