TD-10-014

07/2010

IB3 Press Survey

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Introduction

The objective of this survey was to examine the capabilities and limitations of various presses on the floor of IB3. The three presses being evaluated were the shell welding press, the curing press and the short tooling press (Mangler). Each press was evaluated across several characteristics, including size, pressure, safety factor and deflections. Ideally it would be possible to use at least one of the presses to collar a 4 meter quadrupole magnet with dipole style collars at about 75% press capacity. Additionally, the presses were to be considered for modifications to allow the collaring of HQ type magnets.

Press Overview

The coil curing press is the long press located on the north end of IB3. The curing press is currently configured with heating elements and insulating material on both the top and bottom strong backs. Hydraulic cylinders are located on the top strong back to compress the mandrel for curing operations. Current press capacity is 300,000lb/ft at 7,500 pump psi delivered by 28 Atlas 200 ton cylinders. At maximum pressure, the press is capable of 400,000lb/ft. The vertical workspace in the press is very limited however, at 10.5 in. The minimum clearance necessary to collar is 20” tall by 22” wide. It is possible to raise the top strong back and perhaps achieve clearance; however this would require the removal of the heating and insulating materials as well as removal and rerouting of various electrical and compressed air lines hard plumbed to the upper strong back. The total length of the curing press is 29 feet.

The shell welding press is located on the south end of IB3 near the garage door. It currently is configured with Enerpac 60 ton cylinders spaced 1 foot apart on each side of the press. This gives a maximum press capacity of 240,000lb/ft at 10,000 pump psi or 180,000 lb/ft at 7500

pump psi. The working space in the press is constrained by the welding equipment to approximately 23.5 inches wide by 24 inches tall. Without the welding equipment, the space becomes 33.5 inches wide. The welding press is 24 feet long.

The Mangler is located next to the welding press on the south end of IB3. The Mangler is a short general purpose press capable of up to 600,000 lb/foot depending on its cylinder configuration. In its current configuration, the Mangler offers 23.5” of vertical working space and 18” of strong back width with about 28” of clearance. The Mangler has a length of 7 feet

Press	Linear Cap (7500 psi) [lb/ft]	Max Linear cap [lb/ft]	length [ft]	vertical working space [in]
Mangler	450,000	600,000	8	23.57
Welding	180,000	240,000	24	24.14
Curing	300,000	400,000	29	10.5

As the primary objective was to evaluate the suitability of the presses for collaring 4m quadrupole magnets, the Mangler can be ruled out immediately for its 84” (2.14m) length. Since the current collaring assembly is about 20 inches tall, the curing press can also be ruled out, leaving the welding press the only press capable of fitting the assembly. Size isn’t the only constraint to be considered, as linear capacity is also a major factor. For current collaring needs, the press needs to be able to exert at least 90,000 pounds per linear foot on each side of the coil. Since the welding press is capable of 180,000 pounds per foot total at 7,500 psi, it would be able to meet this requirement with significant margin.

Mangler Press Upgrade

Along with the suitability of collaring a 4m coil, the presses were also evaluated to determine what could be done to upgrade their capacity. The primary concern for the time being was to evaluate the Mangler and its suitability to collar an HQ coil. The goal of an upgrade would be to achieve the same pressures in the magnet coils with their larger size. The press was analyzed to determine if an upgrade would be as easy as replacing the cylinders or if it would require more involved modifications.

In order to determine the maximum that the press could take while maintaining a safety factor of three, its components were evaluated with respect to the yield strength. Components were checked for mechanical failure and excessive deformation. The parts examined were the press support block, threaded rods and upper strong back. The lower strong back was not evaluated as it was constructed in the same manner as the upper strong back but with a wider surface plate. The press was also analyzed using the current cylinders in different configurations to determine if that would be a suitable short term solution.

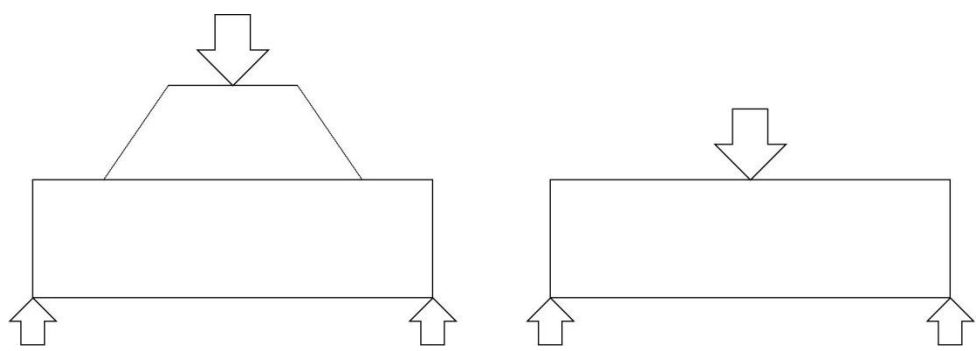
To determine the suitability of the current press rods for an upgraded cylinder, they were evaluated based on tensile area with a specified yield strength of 100ksi and tensile strength of 125ksi. The elastic modulus was determined from a manufacturer spec sheet for the specified AISI-1144 “Stressproof” steel as 2.9E7 psi. The tensile area was determined from the specified thread of 3-8 UN-2A to be 6.51 in^2. To determine the maximum allowable load with a safety factor of 3, the following equation was used

— (1)

Where A_t is the tensile area, σ_{yield} is the yield stress, SF is the safety factor and F_{max} is the max load. This yields a result of 217,000 lb or 108 tons for each rod. Considering that there are already 150 ton cylinders in place, the press is already at a lower than desired safety factor of 2.2 So far, it would appear that the rod is the limiting factor in this design. If the existing cylinders were replaced with 200 ton cylinders, the safety factor falls to 1.6.

If we continue on to the press block, we can determine deflections and possible stresses through classical and computer methods. Since the press block is not a uniform thickness, it can’t be represented very well by classical methods. It is still possible to come up with a worst case type model to analyze the block for undesired behavior. In order to do this, the block was assumed to be a beam at the end cross sectional area. A representation of the simplification can be seen below in Fig. 1.

Figure 1: Representation and simplification of Press Support block



This would result in analyzing a solid steel bar of 7 x 10 x 33 inches. To determine the maximum deflections in this worst case scenario, the beam was assumed simply connected as end displacements and flexing were anticipated to be negligible. To determine the maximum deflection in this case, the following deflection equation was used:

— (2)

Where v_{max} is the maximum deflection, W is the applied load of 2x150T, l is the total length of 33”, E is the elastic modulus of 2900ksi and I is the moment of inertia of 605in^4. Applying the above equation to the simplified beam, the maximum deflection was found to be 0.02”. Keep in

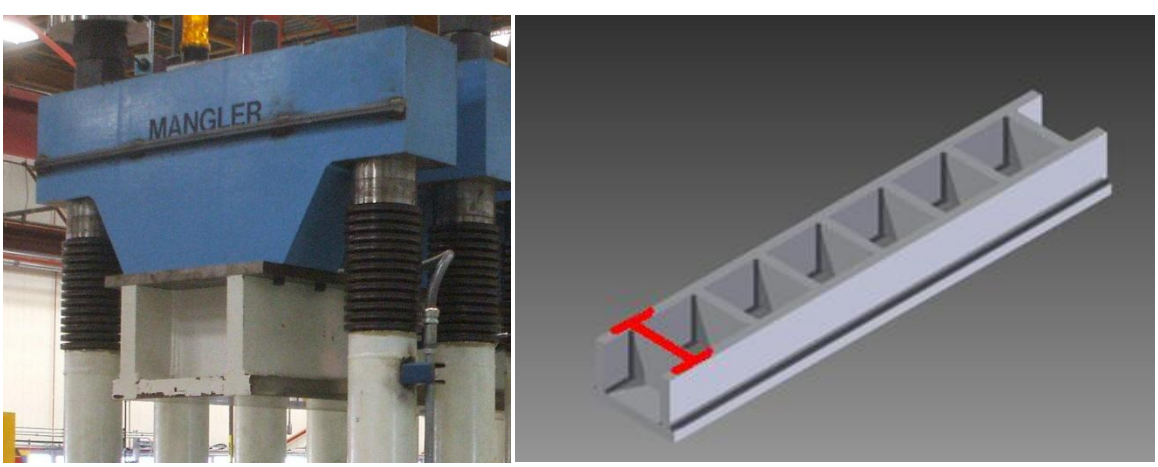
mind that this is a worst case estimate and the actual value would be significantly lower as the actual load is distributed and that the moment of inertia is a function of the cube of an objects height in this case. The simple stresses on the support block could also be evaluated to get a rough idea if its performance. Since the cross section of the block through the center of the bolts has the smallest area, shear stresses can be calculated there to determine its suitability for upgrades. The diameter of the hole is 3.06in leaving a cross sectional area of $40in^2$. If the member is assumed to be in pure shear, the shear stress becomes 7,500 psi. Granted this is somewhere between best case and worst case, but considering it is 1/8 of the yield stress of the steel, there is a fair margin. Continuing on with the simple beam analysis, the maximum in plane tensile stress can be determined. Since the loading on the beam occurs at one point centered on the beam, this will be the location of the maximum stress. The maximum stress is determined through the following equation:

$$\text{—} \tag{3}$$

Where is the maximum stress, M is the internal moment, c is the perpendicular distance from the neutral axis to the point where acts, and I is the moment of inertia. Since the beam is symmetrical about the x axis, the neutral axis falls on the x axis. The moment at the center of the beam can be determined by a force balance. Using this formula, the max stress is found to be 41ksi which is below the yield strength of C1040 HRS which is 60ksi. Once again, this value will also be somewhat higher than the actual stress because of the simplifications used. Even in this simplification, yield is not reached until a load of 880kip or the equivalent of 220 ton cylinders.

The final piece to examine was the strong back. On the Mangler, the strong back is constructed out of 1-3/4in thick C1020 steel with a layer of ¾in HRS between the strong back and the press support blocks. Examining the area of contact between the strong back and upper support block reveals the contact area highlighted in red in Fig 2.

Figure 2: Picture of strong back and contact area



This left a footprint of the strong back on the support block of $43.31in^2$ if the layer of HRS is assumed not to distribute the load. The press load was then considered distributed evenly over that cross section. The maximum stress that this area could handle with a safety factor of three then becomes 736,000lb or 184 tons per side. If the safety factor is allowed to approach 1, the maximum load becomes 2,200,000lb. In order to get a more accurate representation of the stresses, the piece could be analyzed using finite element analysis for a better estimation of the actual stresses.

Now that the components have been analyzed, it's possible to see what modifications are necessary to increase the capacity. Ideally a 50% increase in capacity would be possible; however, given that this is existing hardware, a 33% increase in capacity from 150T to 200T cylinders would be acceptable. If we examine upgrading to 200 ton cylinders as a baseline for feasibility, we can easily determine the practicality of the project. Since the current rods are capable of a load of 108 tons with a safety factor of 3, even the current 150 ton cylinders are exceeding the maximum accepted load. There would be the option of replacing the rods with rods of stronger steel, but with a yield strength of 100ksi, there is very little overhead in terms of other high strength steels. Even if the yield was increased to 150ksi, the max load with a safety factor of 3 would be 162 tons. So in order to increase the capacity by any reasonable amount, the rod size would need to be increased. A rod diameter of 4in of the same material would have a yield strength of $1.25*10^6$ lb or with a safety factor of 3 419,000lb or 209 tons. In order to use the larger rod, the press support blocks would either need to be replaced or modified. A larger diameter rod would also necessitate new support spacers, disk springs and supporting hardware.

In terms of the strong back, an increase to 200 ton cylinders would exceed the maximum safe load computed previously. There most likely is some overhead in that calculation but would need to be found through other methods. In terms of design factors, the Mangler is currently capable of exceeding its design limits and simple upgrades are not possible. Even if the press was upgraded, it would require essentially replacing every component of the current press. Therefore a new press would most likely be a better use of resources.

Another option to consider was using 2 additional cylinders on each over a 4' span for collaring a coil. This could lead to a 2/3 increase in total press capacity, however there is the possibility of deflections at the ends of the tooling. To determine the maximum deflection of the strong back under load, it was assumed to be cantilevered at the end of the tooling and the press support block. The moment of inertia for the beam was computed using the cross sectional area of the strong back neglecting the spacer plate. The moment of inertia of the beam was found to be 575 in^4. Assuming that the load was concentrated at the center of the next support block gives a cantilever length of 8.5". Using the deflection formula for a cantilever:

$$\frac{\quad}{\quad} \tag{4}$$

Where v is the deflection, P is the load, E is the elastic modulus, and I is the moment of inertia. The maximum deflection of the strong back in this configuration would be -.0074" However in the actual press, the tooling and support blocks are elastic and therefore would flex as well. It does appear that it would be possible to collar between 4 cylinders on each side although it would not be in the center of the press. If the coils were to be collared between 4 cylinders, the entire set of press blocks would be entirely supported by the tooling and any deflections should be greatly limited.

References

Niagara LaSalle, *Stressproof*.