TATA STEEL

Unlocking the potential of high-strength steel

Ympress® 100 XF opens up opportunities for lighter excavator arm designs with equal or better performance

Background

In the earthmoving sector, there is significant development in excavators with regard to performance increase, emission reduction and machine intelligence. Lightweight designs could aid these developments. Tata Steel is expanding its high-strength product range to enable such lightweight designs.

Lightweighting using high-strength steels offers benefits in performance, fuel efficiency and machine transportability. To demonstrate mass-saving potential, Tata Steel engineers used advanced modelling and analysis techniques to re-design an excavator dig-end - focusing on the dipper arm - with the use of high-strength Ympress 100 XF.

Excavator dig-ends put high demand on the steel being used. They must have strength to withstand the forces during excavation and they must resist abrasive wear by the material being excavated. At the same time, it is important to minimize the mass of the dipper so that the payload capacity is not compromised or reduced by the weight of the dipper itself. A lighter construction could also allow design freedom to extend reach through a longer arm or, to further reduce counterweight and optimize tail swing design and transportation of the excavator.

Ympress 100 XF hot-rolled steel delivers improved load-bearing capacity without weight penalties due to its high yield strength (see figure 1).

Mechanical properties

The values shown for the mechanical properties and the bend test apply to test samples transverse to the rolling direction.

	Min. yield strength ksi	**Min. tensile strength** ksi	**Min. elongation after fracture A** %	**Bend radius [1])**	
				t < 0.230″	t ≥ 0.230″
Ympress 100 XF	100	110	15	1t	1.5t

[1]) Bend test is performed with polished edges, bend line parallel to the rolling direction

Figure 1: The high yield strength of Ympress 100 XF improves load-bearing capacity without weight penalties

Available dimensions of Ympress 100 XF

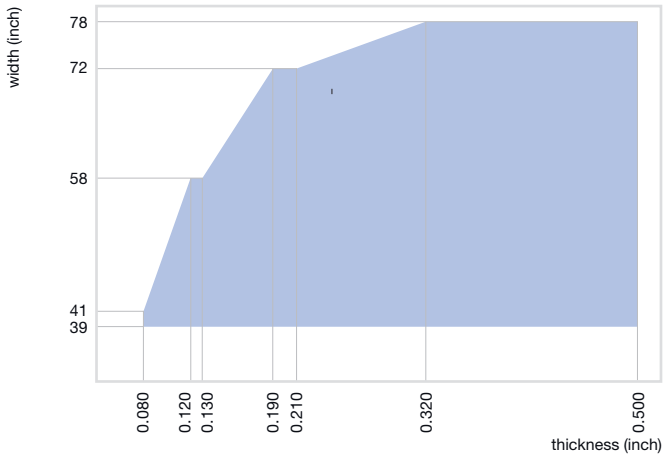

Figure 2: Ympress 100 XF is available in a wide range of dimensions for processing flexibility and efficiency. Other dimensions - including increased thickness - are under development. Please inquire if you need material in dimensions outside the window that is currently available

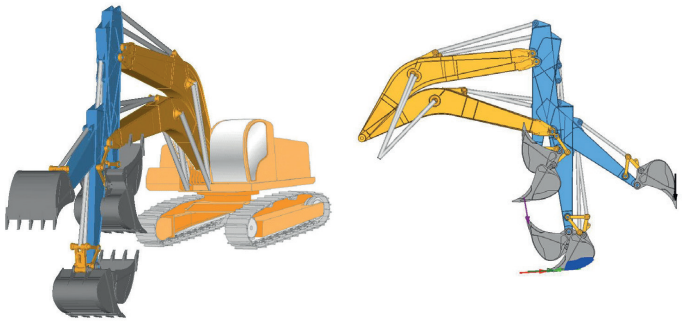

Figure 3: In re-designing the dipper arm, Tata Steel used data from real-life load cases including the forces at play in dig and tamp operations

Modelling and analysis

Tata Steel engineers modelled an excavator dipper arm in the 20 tonnes excavator class. A conventional excavator dipper geometry was selected as the baseline structure. The baseline material was set at A36 grade. The aim of the exercise was to optimize the structure weight.

The dipper arm was modelled into segments - with their thickness set as design variables. The original model weight of the dipper is 920kg, of which 645kg is strip steel (see figure 5). The remainder of the weight is in castings, pins and bosses. For optimization analysis of the dipper, forces were applied at its pins. These forces were extracted from real-life load cases on the whole structure which represented dig, slew, tamp, piercing and lift (see figure 3). Finite element analysis determined the optimum thickness of the strip steel whilst meeting the design requirements for strength and stiffness.

Weight-saving potential

Using computer-aided engineering, gauge optimization on the excavator dipper arm shows a potential for weight saving of up to 23% on strip steel - with all structural performance requirements being met (see figure 6). As the actual geometry of the structure was unchanged in this study, it is possible that further re-engineering of the structure geometry could offer additional weight savings.

	Strip steel weight
Base case	645kg
Optimized case	495kg
Weight saving	23%

Figure 4: Modelling and analysis showed dipper arm weight savings of up to 23% when using high-strength Ympress 100 XF

Cost-saving potential

Applying Ympress 100 XF in a re-designed dipper arm offers cost-reduction potential. Total purchasing cost could decrease - with the weight reduction more than compensating for substitution with a premium steel grade. Manufacturing costs could also benefit as lower gauge material reduces weld time and requires less welding filler material.

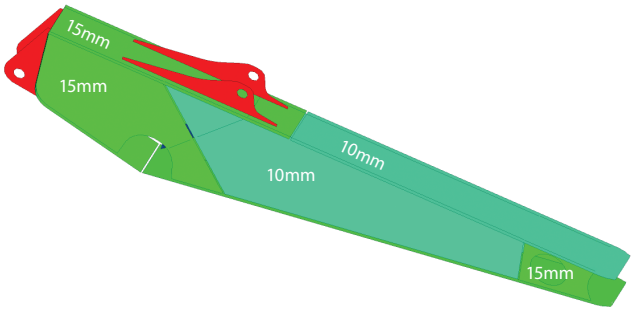

Figure 5: The base-case dipper arm with strip steel segments of grade A36 up to 15mm – with a total weight of 645kg

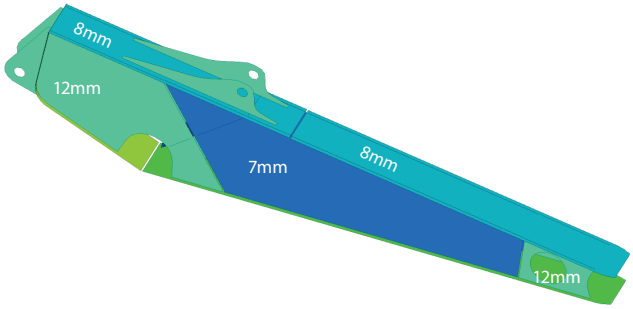

Figure 6: The re-designed lightweight dipper arm with optimized strip steel thickness - allowing potential weight reduction of 23% to 495kg

Conclusion

The study shows that application of high-strength steels such as Ympress 100 XF presents opportunities for lighter, more agile excavator arm designs with equal or better performance. Use of Ympress 100 XF in lightweight designs also offers cost-saving potential. Extending this exploratory study to the full dig-end structure would enable identification of increased opportunities to save mass in the boom and optimize performance, tail swing and transportation.

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