Ultra lightweight core bit from Western Saw

US company, Western Saw, who this year celebrated its 80th anniversary as a manufacturer of diamond saw cores, carbide plate bodies and diamond core bits, recently initiated a redesign of its lightweight SpokeBack™ diamond core bit. The project was called Ultra™. The scope of this project was to increase the stiffness and torsional load capabilities and further reduce the weight while maintaining the ability for the user to open the backend in case of a stuck bit. In addition, the company targeted a reduction in costs by decreasing manufacturing time, increasing material yield, and by eliminating drilling and tapping operations. Report by ***Anthony Baratta****.*

Fig 1 The new Ultra core bit range from Western Saw

Western Saw's Research and Development team started work on the design of its new Ultra core bit by initially benchmarking the load capabilities of both the SpokeBack and SolidBack™ back ends from its present lineup. This was accomplished by creating computer solid models that replicated the backend geometry. Then utilising the latest finite elemental analysis (FEA) and simulation techniques, static studies were performed which clearly illustrated the location of stresses as well as the degree and location of deformation and strain. After the static studies, a frequency study was conducted to identify the various nodes of vibration and verify that the back end was not operating at or near a natural harmonic frequency.

In addition to the frequency study, a thermal study was conducted to determine the thermal stresses due to heat flux and heat power generated by the drilling action. All of the data from the fore mentioned studies were then entered into a fatigue study to help define an appropriate path for research and development to design and optimise a new stiffer, lighter back end.

Once the numerous FEA study results were post analysed, they were compared to empirical data collected from laboratory tests of load vs. deflection gathered using a load cell, a hydraulic press and a dial indicator. Any anomalies seen in the results of the simulation with respect to the lab tests were corrected by adjusting the FEA material properties and re-simulated until they matched. This iterative process allowed R&D to condition the models and derive the simulated material properties so they could model and simulate several new designs in the computer, which they knew would accurately replicate actual load conditions and materials.

Performing this process before creating prototypes for final design verification and eventual field testing saved development time and cost by honing in on the optimal design before having to produce any physical parts or assemblies.

The results of the load vs. deflection and weight vs. tube diameter for the back ends are shown in Fig 2.

Design concept

The design target of the Ultra was set to match the deflection vs. load of the SolidBack whilst reducing the weight by an average of 50% of the same sized SpokeBack.

R&D's design concept was to utilise thin radially offset interlapping vertically arranged steel supports, called spars, notched into a drive plate, which when welded together gave the desired load characteristics of a solid 0.50" (12.7 mm) steel plate while significantly reducing the overall weight (Fig 3).

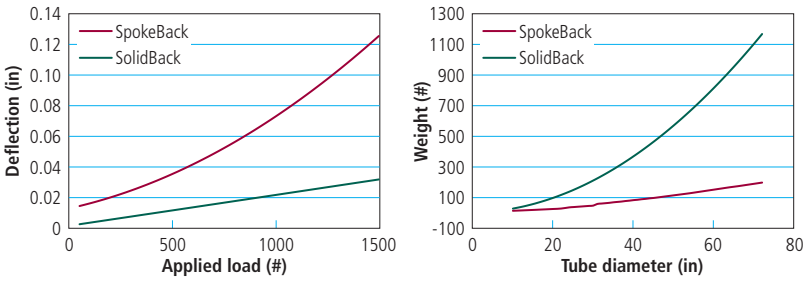

Fig 2 Load/deflection and weight/diameter comparisons for the SolidBack and SpokeBack

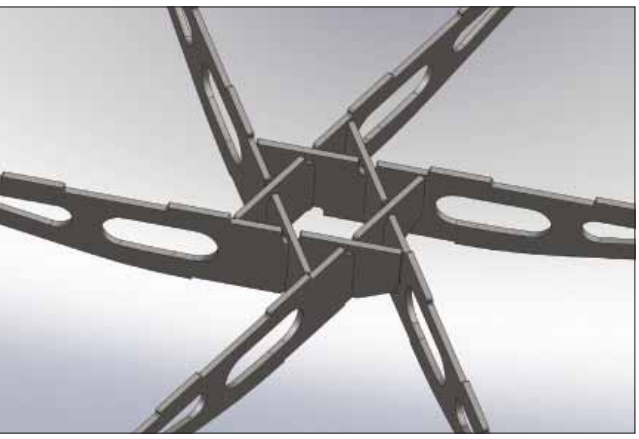

Fig 3 Radially offset interlapping support structure

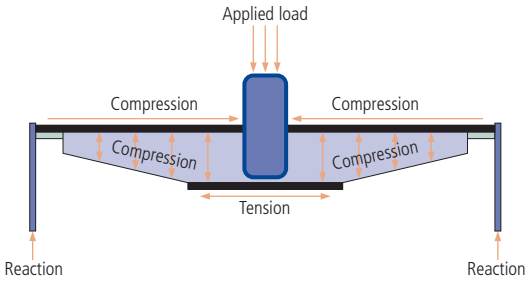

Fig 4 Load distribution on the drive plate, shear plate and spars of the Ultra

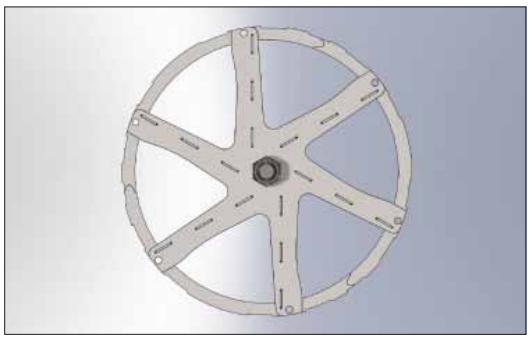

Fig 5 Overview of Ultra's offset spar design

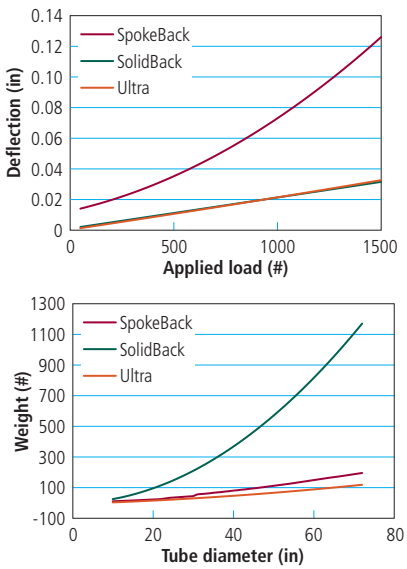

Fig 6 Load/deflection and weight/diameter comparisons for the SolidBack, SpokeBack and Ultra

The radially offset interlapping spar structure also creates a hexagonal shaped pocket in the centre of the drive plate that receives and locks-in the drive nut similar to a socket used on a ratcheting wrench. The drive nut is then welded to the drive plate and shear plate located at the top and bottom of the support spars respectively, which adds additional structural support to further reduce the deflection when vertical loads are applied.

Since sheet steel is rolled, it can be considered anisotropic because it has slightly different stiffness properties that vary from the direction of roll. For this reason, simply cutting the spars perpendicular to the direction of roll and rotating them on end increased the stiffness in the direction of the applied load. Once the spars are inter-lapped and welded to both the drive and shear plate, the structure acts similar to several I-beams radiating from the axis of rotation to the periphery of the tube. For this reason the material can be much thinner than the thick plate presently used on the SolidBack and SpokeBack designs and thus giving the Ultra the desired lighter weight.

Compression and tension

The neutral axis is an axis in the cross section of a beam or shaft along which there are no longitudinal stresses or strains. If the section is symmetrical and is not curved before a bend occurs, then the neutral axis is at the geometric centroid. All fibres on one side of the neutral axis are in a state of tension, while those on the opposite side are in compression (Fig 4). Therefore, while under drilling conditions the drive plate and the shear plate see compressive and tensional loads respectively, and the spars only see compression. In the event of lifting the tube out of the hole with a concrete plug stuck inside, the drive plate and the shear plate see tensional and compressive loads respectively, and the support spars see tensional loads only.

Furthermore, by increasing the distance between the drive plate and the shear plate, the stiffness goes up significantly while adding only a fractional amount of weight. This is why the depth of the Ultra backend is 2" (50.8 mm) measured from the top of the tube compared to 1.0625" (26.98 mm) of the SolidBack and SpokeBack.

Offset spar design

When there is a bending moment at a section through a structural element, the moments can be summed about that section of all external forces acting to one side of that section. The forces and moments on either side of the section must be equal in order to counteract each other and maintain a state of equilibrium so the same bending moment will result from the summing of the moments, regardless of which side of the section is selected. As a result, there is no direct line of action through the axis of rotation, and a moment is created between the offset spars which forces the other spars to distribute and share the load (Fig 5).

The Ultra also has a unique water distribution system which takes water supplied from the shaft of the drill motor through the drive nut where it hits the shear plate and is forced out through openings formed by the inter-lapping spars. Under rotation the water is flung to the inside of the tube barrel and driven down to the cutline.

As illustrated by Fig 6, the Ultra is within the design target of matching the SolidBack's deflection at an average of 50% the weight of a SpokeBack.

The result of the research and development teams efforts are clear; A stronger, lighter, stiffer diamond core bit that maintains the ability for the user to open the backend in case of a stuck bit. The patent pending Ultra is available in sizes ranging from 350 mm to 2500 mm. ◆

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