DESTRUCTIVE TENSILE TESTING OF STEEL CORDS USED IN THE MANUFACTURE OF STEEL CORD REINFORCED CONVEYOR BELTING.

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INTRODUCTION

As a result of certain steel cord reinforced conveyor belt failures in 2002 it was required that individual cord strengths be measured. Conveyor belts had failed in service and apart from production losses, the real possibility of loss of human life existed. Destructive testing carried out by local test authorities following the older method prescribed in SABS 1366 gave results suggesting cord strength deterioration. An alternative explanation implying that the method of test prescribed in SABS 1366 was inaccurate was then investigated. It was found that the methods being used were indeed inaccurate, and in some cases grossly so. Alternative cord break test methods were then researched in order to establish a method yielding reliable results and therefore allowing the manufacturers of steelcord conveyor belts to offer a more reliable product, based on accurate cord tensile strength information.

EXISTING PRACTISES

All manufacturers of steel cord reinforced belting have traditionally accepted the values on certificates supplied with cords from various steel cord manufacturers. Specification SABS 1366 of the time described a test procedure whereby the cord strength could be determined after manufacture; this test has proved to be unworkable and unreliable.

Numerous tests of cord strengths carried out by local test houses using this procedure indicated strengths far short of those certified by the cord supplier, which was obviously a source of considerable embarrassment to the manufacturer of the belt and ultimately to the test houses themselves. This situation led to the need to investigate the method by which the cord manufacturers tested steel cords in comparison to the SABS method. It was found that cord suppliers also used a method that returned inconsistent results and numerous test values supplied have since been proven to be incorrect. The global method of testing was thus also considered to be unreliable as none of the available standards worldwide contain a test method that is considered to be reliable or consistently accurate.

The inconsistencies that prevailed are a consequence of the method of test. Due to the very high strength per unit of area, steel cords must be very securely fastened in the test machine. Two distinctly different methods have previously been employed. The first is some type of ferrule attached to the cord and then held in the jaws of the test machine, while the second relies on the cord being embedded in a white metal casting which in turn is held in the test machine.

A currently acceptable method of testing large diameter wire ropes involves the use of white metal, and this method was extended into the testing of steel cords for conveyor belting. White metal methods impose certain challenges, including cost, environmental and safety. In addition the application of excessive heat in applying the white metal has a tendency to anneal the high tensile steel wire filaments and to consequently weaken them during test preparation. Tests carried out utilising an alternative low temperature medium as opposed to white metal, have proved this theory beyond doubt.

POSSIBLE ALTERNATIVES

The following research and development was carried out into the evolution and the formulation of an alternative product to the white metal used previously. The advantages to manufacturers carrying out accurate, consistent tensile strength tests would be that these values could be used when designing belts, leading to savings by both the manufacturer and the user.

As an example of cost saving, many tests carried out over the last 3 years, utilising the alternative method have proved that a certain international Eastern supplier of steel cord to the world market for conveyor belt manufacture, is consistently supplying cord with a tensile strength exceeding their stated maximum (as opposed to specified minimum), by a figure of 13%. If this is translated to a belt with a design strength of say 2500kN per metre width, having a total of 77 cords each of 5,4mm diameter, each cord having a designed breaking load of 32,6kN, then 13% over maximum would result in a belt strength of 2836kN per metre width. Leaving aside certain conveyor belt design parameters such as cord pitch etc, a total saving on a belt of 10,000 metres length would be in the region of 90,000 metres of steel cord, that is 68 cords each of 36,8kN breaking load as opposed to 77 cords of 32,6kN breaking load.

As recently as 11/05/2005, a 7,6mm steel cord of 19+7x7 construction, manufactured by a European cord supplier of high world repute, was tested to verify tensile strength. The test was varied slightly by way of reducing the jaw separation speed in the tensile testing machine to 25mm per minute in line with the Australian steel cord tensile break specification. In South Africa, as in Europe, a separation speed of 100mm per minute is specified in the respective national standards. The supplier's test certificate stated that the minimum breaking load is 52,70kN, and the maximum achieved in their laboratory test is 55,86kN. Using the proposed method of testing and a jaw separation speed of 25mm per minute, a value of 59,20kN was achieved. Bearing in mind that the conveyor belt manufacturers have designed their belt using 52,70kN as the individual cord breaking load, and ordered cord accordingly, then final belt over strength is calculated at 12,33%. The potential for cost saving, if accurate consistent and reliable test results are available, can be seen to be considerable.

The lower separation speed of 25mm per minute results in the more accurate values, as it allows the individual cord filaments to partially overcome the high co-efficient of friction inherent within the cord as initial tension is applied, and thus contributes to improved load sharing.

In support of this, consider the initial loss in cord strength of possibly 4% during a typical steel cord conveyor belt production vulcanising cycle at approximately 155°C. When the fully rubberised cord is removed from a production sample of belt and re-tested for tensile strength (a very lengthy and rarely successful process), the cord strength is fully regained, as a result of favourable internal frictional issues between the cord and rubber. Thus a steel cord of say 60kN bare strength will lose approximately 2,40kN initially during vulcanisation, and the regaining of this strength in the rubberised cord cannot be attributed to the tensile strength of the extremely small amount of rubber compound which has penetrated between the filaments. The rubber between the filaments acts as a 'separator', reducing the friction between the filaments and thus allowing increased load sharing. Overall cord strength is therefore back to where it started before manufacture, and indications are that rubberised cord tensile strength may substantially exceed that of the virgin cord. The proposed method of testing has already prompted some cord manufacturers to have independent tests carried out by universities, and subsequently finding that the current method is indeed outdated.

RESEARCH AND DEVELOPMENT.

A consistent, reliable, accurate and cost effective method of testing steel cords was therefore required, and in addition it would be necessary for the selected equipment to meet certain criteria: -

a. The test equipment and media selected would be required to grip each individual steel filament in such a way that no deformation or damage to the secured filaments occurred during testing, and that filament load sharing would be as uniform as possible. By way of explanation, a steel cord used in the manufacture of steel cord re-inforced conveyor belting may contain as many as 133 individual steel filaments. This number of filaments would be present in a designated 7 x 19 steel cord, that is 7 strands of 19 filaments each manufactured into one steel cord.

b. As steel cords used in the manufacture of steel cord re-inforced conveyor belting rarely exceed 12mm's in diameter, the filaments therein are extremely fine, easily damaged during testing, and very susceptible to heat degradation at temperatures exceeding 150 degrees centigrade. The test media selected would therefore have to be of a type that did not exceed 150 degrees centigrade during preparation and/or cure. This condition effectively excluded any form of white or soft metal utilisation. The temperature at which these media become liquid, far exceeds the maximum desired.

In conjunction with a metallurgist employed by a global mining house, as well as with numerous industrial chemists and design engineers, many hundreds of tests were carried out, centering on the chemical bonding of the steel filaments within a simple toughened steel mould. The cone shaped design of this mould provides mechanical assistance during testing by way of its compressive wedging action on the cured media within the mould. The very high co-efficient of friction between the media and the steel filaments coupled with the wedging action, provides extremely consistent, reliable, cord breaks and test results. It was necessary for the mechanical components to be easily utilised in most Instron testing machines, and for the media and mechanical test equipment, as well as the preparation of the steel cords and media, to be user friendly. All of this has been achieved.

It was known at the time of research that a British company had previously developed and was supplying a test medium that satisfied the necessary criteria. However, the cost of this media was at the time in the region of R200.00 for each destructive tensile test performed in a laboratory. International European based suppliers of steel cord to the world considered this cost to be unacceptably high and testing using the particular product was discontinued at their facilities.

LOCALLY DEVELOPED

The locally developed media is costed at approximately 10% of this figure or R20.00 per test. The media consists of a specifically formulated, pulverised, unsaturated polyester resin, dissolved in styrene monomer containing low levels of inhibitors to prevent premature polymerisation, accelerated with di-methyl amine of design strength, and catalysed with di-benzoyl peroxide in powder form. Inert silica of a specific granular size, MOHS hardness and particle shape is added to provide the required mechanical grip. The media does not exceed 140 degrees centigrade during polymerisation (cure) and is ready for tensile testing within approximately 60 minutes of pour, depending on ambient air temperature.

To date approximately 550 successful destructive steel cord tensile tests have been carried out using this specific polyester resin as the medium. Of interest is the fact that on three separate test occasions, certificated tensile strengths from the cord suppliers have proved to be overstated. The consequences of under strength cords being used in belt manufacture could have serious consequences for the end user.

ENVIRONMENTAL AND SAFETY ADVANTAGES.

Polyester resin has distinct advantages over the use of ‘white metal’

a. Operator safety is greatly increased by the relatively low degree of temperature of the curing medium, as opposed to molten metal, exposure to which is highly dangerous.
b. Inhalation of heavy metal fumes during white metal smelting (cumulative and highly detrimental to human health) is eliminated.
c. Cured polyester resin is relatively inert and will not leach into either soil or underground water systems if incorrectly disposed of.

SANS-1366. AS REVISED 2005.

The standards committee of the SANS (conveyor belting) was approached during 2003 and requested to consider incorporating the alternative method of steel cord tensile testing into SABS 1366 of 1982, now revised as SANS 1366 - 2005. The method and procedure for testing in SABS 1366 –1982 was unworkable, almost totally unreliable and largely ignored by the South African steel cord conveyor belt manufacturers. After due SANS committee deliberation I am pleased to note that the alternative method of testing will now be incorporated into SANS 1366 of 2005.

However, it is disturbing to note that the test as incorporated, is not obligatory, and manufacturers of steel cord belting may still rely on the steel cord suppliers certification if they so wish, and if not otherwise required by the end user. This may prove to be a retrograde step, and as the alternative test is both simple and cost effective, the reasoning behind this decision is uncertain, especially in view of the potential long term cost savings. Applying an accurate cord break strength test would allow cord manufacturers to maintain stricter control over their own manufacturing processes, if aware that cord tensile strengths would be verified and not accepted at face value.

On a positive note, certain large progressive end users of steel cord conveyor belting in South Africa are indeed insisting on the verification of steel cord tensile strengths before belt manufacture commences. The existing SANS specification 1366 –1982, implies the testing of three samples of production belting. (Belting already being produced in the vulcanising presses).

As, in the opinion of the author, laboratory prepared samples, cannot be fully representative of a production belt, then testing after belt production commences could prove to be disastrous to all parties concerned.

CONCLUSIONS

- It can be seen that industry in general requires peace of mind regarding steel cord strength, and therefore belt strength. This applies equally to over or under strength cords.
- The existing cord test methods do not provide consistently accurate results, and in the long term industry is paying for it.
- Modern methods are available that can provide more accurate results, that will save industry money in the long term.
- These methods are less expensive than the current methods used.
- These methods are environmentally friendly and safe to the operators of test machines.

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