DYNAMIC LOADING ON ENGINEERING MATERIALS AND COMPONENTS

C. Wilson*, P.Kerry* and O Crichton*

The United Kingdom Health and Safety Executive's Health and Safety Laboratory (HSL) is currently undertaking a number of research programmes to investigate the effects of dynamic loading on engineering materials and components.

This paper describes the Laboratory's 1MJ impact facility and outlines some of the current work programmes. These include: investigating the effects of dynamic loading on locked coil wire rope, effects of impact loading on lifting components and techniques for investigating the strain rate effect on large tensile test specimens.

INTRODUCTION

The 1MJ large impact test facility occupies part of the Laboratory's 220ha site, located on the moors above Buxton in Derbyshire. It has been in use for a number of years and was modified recently to extend its capabilities.

The facility includes a pair of railway lines running down opposing valley slopes. The Southern 1.09m wide outer track is 100m long at an incline of 1 in 7 with a further 80m of 1 in 4 incline. The Northern 0.38m wide inner track is also 100m long at an incline of 1 in 7. Both opposing tracks meet and overlap at the bottom of the valley at a flat 20m impact section. Adjacent to the impact point, at the valley bottom, is a control and instrumentation laboratory.

Several large impact vehicles, with masses up to 9500kg, provide the necessary kinetic energy for a range of tensile and compressive tests.

*, Health and Safety Laboratory, Buxton, Derbyshire, United Kingdom.

Electric winches and a computer operated release system permit controlled collisions at the instrumented impact point. Accelerometer, load cell and straingauge signals are transferred through umbilical cables back to a high speed multi-channel 10MHz data acquisition system. An in-house designed and manufactured linescan camera, operating at 150μs/scan and digitally storing its image, is used to provide dynamic elongation and strain rate information.

IMPACT TESTING OF COMPONENTS AND MATERIALS

Locked Coil Winding Rope

Most United Kingdom deep coal mines use locked coil wire ropes, manufactured to National Coal Board Specification 186 (1), to raise and lower cages in the shafts. This type of rope is made from concentric layers of shaped wires instead of the more traditional method of using multiple twisted strands each made up of circular cross section wires. The locked coil design produces a much stiffer and stronger wire rope. Some disadvantages of the design are that the rope is less flexible and it has a much lower elongation to failure; typically 5%.

Occasionally, during use, these ropes are subjected to accidental dynamic loading. If the rope has suffered obvious visual damage it will be replaced. If damage is not visually apparent the rope may be left in service. A particular problem is that on-site visual inspection may not identify localised plastic deformation.

To provide additional inspection information the Laboratory was contracted to measure dynamic breaking loads, elongation to failure and how the energy absorbing capacity of 19mm locked coil winding rope varies with sample length.

Test Method. The impact facility was modified to enable ropes up to 50m in length to be tested - Figure 1. Earlier work had shown that if the sample of rope was not carefully positioned and held under tension the reduction in performance was considerable. A slack rope sample can 'whip' at impact causing premature failure at the rope terminations (cappings).

A ground anchor vehicle was used to secure one end of the sample rope. The other, impact end, of the sample was secured, with a high tensile 'T' piece, to a hydraulic pre-tension vehicle. The 6300kg impact vehicle was released and allowed to run down the track. It passed over the rope sample, collecting the 'T' piece at the impact point. The 'T' piece was designed to break free as the impact vehicle followed through.

Load cells positioned in the rope cappings transmitted signals back to the data logging system. The linescan camera, located adjacent to the impact point and focused on the end of the rope sample, determined the failure elongation. This camera recorded elongations approaching 2.5m, with a resolution of 2.5mm, at a recording rate of approximately 6500 scans per second.

Results. Figure 2 shows the comparison between the static reference tests and a typical dynamic test. The dynamic results indicate that a wire rope sample has significantly less energy absorption capability, even though the ultimate failure load is approximately equal to that of the static result. Other results raise the possibility that, in small dynamic overloads damage may occur at the ends of a rope, even when the total energy would be too low to cause damage in a static test. Therefore measuring overall length for an indication of permanent set, after an accidental dynamic overload, is not an accurate indicator of rope condition and remaining rope life.

High Tensile Grade T(8) - Lifting Equipment

Background. United Kingdom accident statistics frequently report that lifting equipment has failed due to dynamic/shock loading even though 'adequate' factors of safety have been employed. A research programme was devised to determine the fracture criteria for samples of 16mm Grade T(8) lifting chain and hooks, manufactured to British Standard 4942 (2), containing various service defects. These defects were fatigue cracks introduced by notching and then repetitively loading the components above their rated working load.

Method of testing. The technique for dynamically impact loading samples of lifting chain or hooks differed somewhat from the method previously described. For very rapid impulse loading of short components the sample under test was positioned in a 9500kg specimen truck - Figure 3. This specimen truck, designed to withstand dynamic forces in excess of 3MN, was released to run down the Northern slope on the inner track. A 5000kg hammer truck, simultaneously released, ran down the opposing Southern slope, on the outer track. The hammer truck passed over the specimen truck striking and connecting with the sliding 'flying arm'.

Discussion of results. The dynamic force/time results - Figure 4, shows three traces: (a) is the result from an 'as received; undamaged sample with a breaking load of 230kN, (b) a lightly fatigued damaged sample with a breaking load of 217kN and (c) failed at 163kN with a more severe fatigue crack. Superimposed is the 322kN failure load from a static test on an undamaged sample of chain. All forces were recorded to an accuracy of ± 3%.

The fatigue cracks also reduced component energy absorption capability. This was indicated by the time to failure and elongation to failure (not shown). For a consistent impulse, new chain broke in 42.0ms, with the two fatigue damaged samples failing at 4.1ms and 3.6ms respectively. The results from this programme, and the yet to be completed hook phase, will be used to determine inspection and discard criteria as well as validate factors of safety.

Large Scale Tensile Impact Testing

Background Information. Many safety case analyses for structures as diverse as offshore rigs and nuclear reactor vessels use dynamic finite element modelling packages containing material strain rate properties derived from small scale tests.

This programme of work involved, devising a large scale impact tensile test technique and determining the dynamic characteristics of a metallic material that has well-documented static and small scale dynamic properties. The material selected was Grade 50 steel to British Standard 4360 (3). The dynamic data from these tests will be correlated with the documented data from small scale tests. To determine variations between calculated and experimental data the tensile test specimen will be modelled using the LUSAS dynamic finite element package.

Dynamic Tensile Test Technique. The impact facility will be reconfigured so that the chain sample is replaced by a large tensile specimen. This tensile test specimen has an overall length of 825mm, a gauge length of 225mm and a cross sectional area of $1964 mm^2$. Straingauges will record longitudinal force and the linescan camera positioned and focused on the gauge length will record the elongation with a resolution of 0.25mm. The experimental and analysis part of the project will be completed by Autumn 1996.

REFERENCES

(1) United Kingdom - National Coal Board specification 186 'Locked coil winding ropes'.

(2) British Standard 4942-1985 ' Short link chain for lifting purposes'.

(3) British Standard EN4360-1990 'Specification for weldable structural steels'.

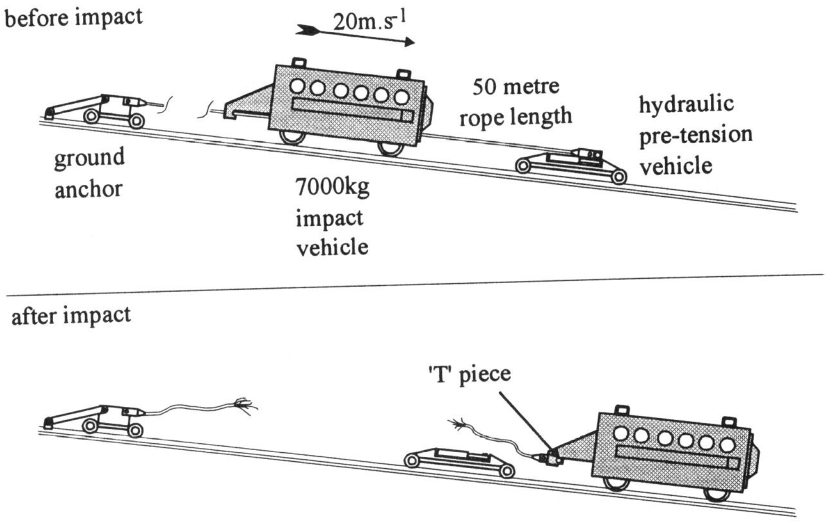

Figure 1 Impact facility set up to test locked coil wire rope samples

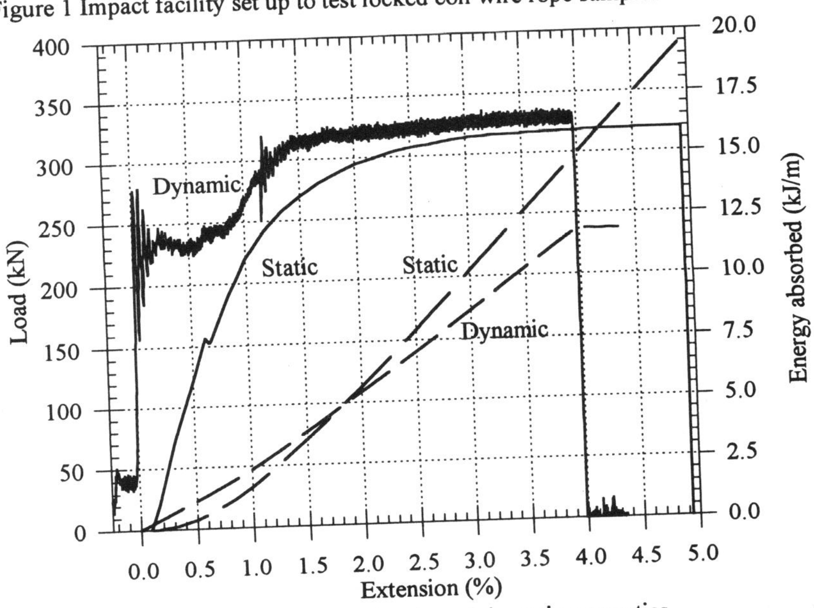

Figure 2 Wire rope - comparison of static and dynamic properties

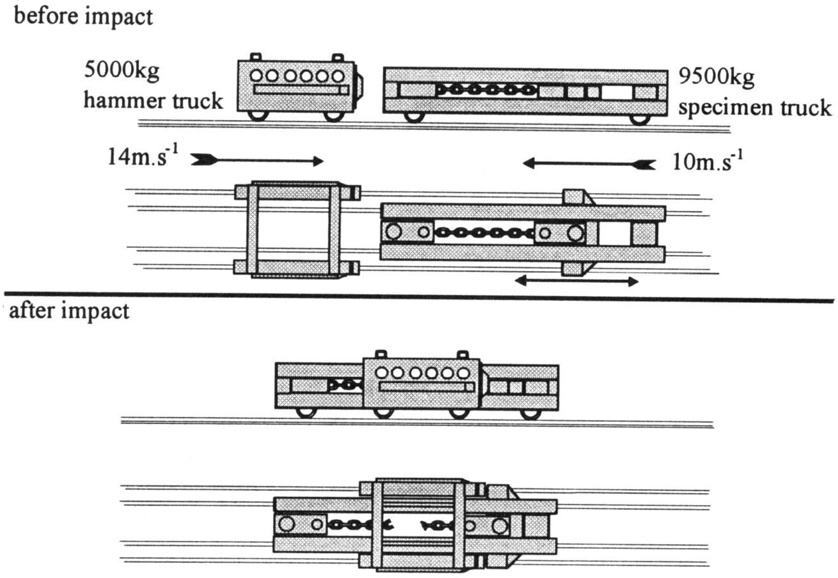

Figure 3 Impact facility set up to test large tensile specimens

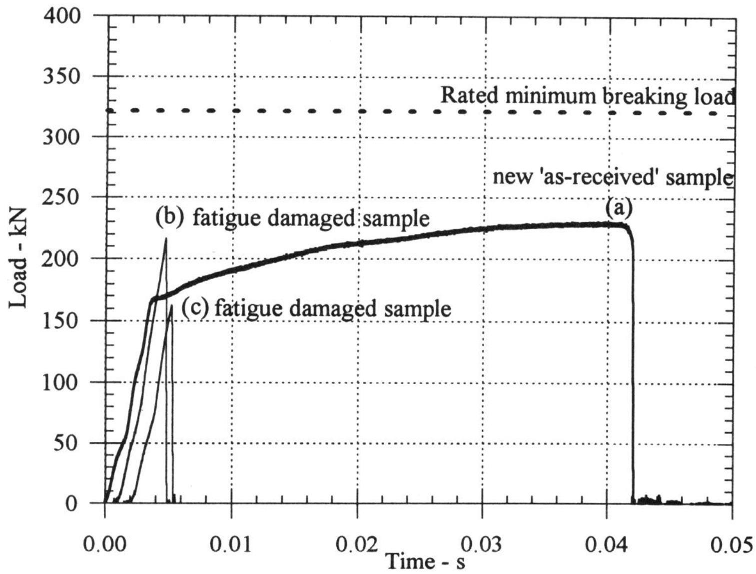

Figure 4 Typical chain samples force-time characteristics