PRACTICAL ASSESSMENT OF THE "DAMPING" EFFECTS OR "QUIET" LASER CUT CIRCULAR SAW BLADES

Mr K A Broughton, Health and Safety Executive, Magdalen House, Stanley Precinct, Bootle, Merseyside, UK

INTRODUCTION

The noise levels created by circular sawing operations have always been known to be excessively high. The application of circular sawing is related to many industries, and can result in very high noise exposures for the operators, these may be in excess of an L_{EPd} of 100 dB(A). The only effective way to reduce such an exposure is to where possible enclose the operation, but this is not practical in the majority of situations and therefore hearing protection is often the only choice of control.

Many learned papers have been written on the causes of noise from circular saws, and many differing designs of tooth shape, spacing etc have been attempted. True damping of the body of the blade has been tried and in many situations proven to give good results, but not without creating other problems when the saws have to be reconditioned.

This paper looks at a treatment which can be applied to not only new blades but also to blades which require refurbishment.

Mechanisms of Noise Production

It is recorded from many sources that the noise from circular saws can be attributed to the following effects :-

1. The aerodynamic disturbance in the vicinity of the saw blade.

2. Blade vibration (sometimes at resonance).

3. The interaction of the teeth with the material being cut.

4. Workpiece vibration.

Aerodynamic effects :- this is usually a disturbance (manifesting in a "hissing" sound) from the tooth and gullet areas of the blade. Occasionally, for some circular saws during 'idling' the frequency of the aerodynamic excitation forces coincide with the blades natural frequency, and the blade is induced into a state of resonance. Which is responsible for a high intensity scream or whistle.

Blade vibration :- As well as resonant forces blades may be excited by lateral or radial imbalances in the blade, or by vibrations transmitted from the spindle.

Under resonant conditions the blade will not only produce more noise during idle but also when cutting. In this latter case, however, the pattern of blade vibrations will be even more complex and will include the forced vibrations introduced by the impact of the saw teeth with the workpiece.

Interaction noise :- This is caused by the impacting of the teeth on the workpiece giving rise to a clear "tooth passage frequency". "(TPF)".

Workpiece vibration :- Resonance of the workpiece is usually more significant when materials such as metal (especially aluminium), plastics or other materials known to be vulnerable to excitation are being cut.

Laser-Q Saw Blades

The original design of the Laser-Q circular saw blade was conceived to reduce the tooth tip vibration giving a cleaner and more efficient cut in the material. It was not surprising that this reduction in blade vibration also resulted in a corresponding reduction in blade-vibration-induced noise, a beneficial "by product".

Up until the middle of 1990 the marketing strategy for these blades was aimed at the "cleaner cut" aspects, with noise reduction being kept as "low-key" benefit. A company of noise consultants, Philip Dunbavin Acoustics Ltd were impressed by a quieter running circular saw on one of their visits associated with a consultancy project. This prompted an approach to the company Ernest Bennett (Sheffield) Ltd with a view of quantifying the low noise claims associated with the product. Initial tests showed noise reductions of between 0.0 dB(A) and 6.1 dB(A) with an average of 3.2 dB(A) could be achieved. Whilst the results appeared not to be consistent, they did show potential.

These advertising claims were quickly recognised by a Specialist Noise and Vibration Inspector of the HSE and funding became available for a limited series of tests of the Laser-Q blade under a wide range of conditions. A research proposal was prepared by Philip Dunbavin Acoustics Ltd and ultimately the contract for the work was placed with them.

From the outset it was apparent that a "truly comprehensive" study was not possible due to the financial restraint of the contract, but it was felt that in the time available clear trends would emerge, allowing positive conclusions to be drawn.

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Design of the Laser-Q Saw Blades

The laser-Q blade is essentially a standard blade which has had the edition of lasered slots cut into the body of the disk. These slots are of a width dependent upon the disk thickness (usually between 0.2 and 0.4 mm) and tend to occupy about 15% of the overall blade diameter.

The fine slots resemble elongated "S" shapes terminated by a small diameter hole, which are then spaced equi-distant around the disc. Numbers being dependent on the diameter of the disk. An example would be for a blade of 350 mm diameter, 8 slots would be cut into the disk.

After cutting, the slots are then impregnated with a non-metallic resinous substance, which when hardened help to counter the weakening effect of the slots.

Applications

The system is extremely flexible being able to cope with various blade diameters from 150 mm to a maximum of 1.5 m. Blade thickness is also not a problem as cuts can be made in any reasonable thickness of disk.

The principle of cutting the slots is not confined to blades used to cut wood and wood products, the system is just as applicable to high speed metal cutting or stone cutting.

New blades can be given the treatment and also blades due for refurbishment can be laser-cut when sent for renewal. The cost of such a retro fit to an existing blade for example would be £16.00 for a 12" diameter blade (cost 7/8/91).

Mechanism for Reducing Noise

It is believed that the noise produced by the disc of a saw is generated by the formation of auxilliary-circling, flexural waves in the disc body. The action of cutting the lasered slots in the disc body is to prevent the formation of these flexural waves building up in the disc, giving a noise reduction as compared with untreated blades.

When the simple test of tapping a treated and untreated disc is carried out. The untreated blade rings out quite clearly. Whilst the treated blade the "ring" is virtually eliminated. To the casual observer the difference using this test is quite remarkable.

Practical Testing

Due to the limited contract the consultants were commissioned to carry out testing in practical situations. The noise from a normal saw, identical in diameter, number of teeth etc was compared with a saw having the laser-cut treatment. Used in all the following test situations :-

1. A circular rip saw cutting timber and man-made boards.

2. A circular saw cutting aluminium or brass extrusions or pipes.

3. A circular diamond cutter cutting concrete products.

In each case a selection of materials were cut and the noise levels measured.

Testing Techniques

The tests were carried out by placing a CEL 393B sound level meter in representative operator positions close to the cutting area of the saw. The sound level meter output was then recorded using a Sony-pro Walkman for later analysis. All tests were repeated until sufficient representative data was obtained. The analysis of the tape was carried out by feeding the signal back into the CEL 393B via a dummy microphone. The following parameters were thus obtained :-

1. $^{1}/_{3}$ octave band leq levels with centre frequencies of 25 Hz to 20 kHz.

2. dB(A) leq readings.

The analysis system was also calibrated to give an accurate correction curve for the frequency response of the whole system.

All results were entered onto an extensive computer spread sheet for further manipulation, this included the calibration correction curve which was subsequently built in to all of the results.

PRACTICAL TESTS

Wood Cutting :- Both treated and untreated blades were tested on a variety of materials and sections. The blades were run in a Wadkin-Bursgreen/Cross cut saw (also capable of rip sawing) at a measured rotational speed of around 2996 rpm, the blade having 55 TCT teeth, which gives an anticipated tooth passing frequency of 2.7 kHz. This was subsequently seen as the dominant peak in the results. The noise level was also compared with the blades running free (non-cutting).

An example of the graphical results is given for the free running conditions (Fig 1) and for a ripping operation on a piece of 4" x 2" soft wood (Fig 2). These graphs also illustrate the dominant tooth passing frequency. As can be seen from these two tests, reductions in noise levels by the Laser-Q blade was 2.4 dB(A) for the free run and up to 6.4 dB(A) for the 4 x 2 ripping operation. All other materials showed an overall reduction of between 0.7 dB(A) and the 6.4 dB(A) illustrated.

Flag Stone Cutting

All materials tested were compounded concrete products of varying thicknesses, Both blades were tipped with a segmented diamond matrix and for these tests run dry in a hand held angled saw. The free running speed of the saw was measured at 4,460 rpm reducing to 3,890 rpm under conditions of load. Both blades had 18 segments with an expected tooth passing frequency (TPF) of 1 kHz under load which was not so obvious as the TPF shown in the wood cutting tests. The free running comparison of results is shown in (Fig 3) giving an overall slight increase in noise level (0.6 dB(A)) for the Laser-Q blade. The cutting of a 600 mm x 600 m x 35 mm paving slab produced a reduction in noise for the Laser-Q blade saw of 2.8 dB(A) shown in (Fig 4). It is worthy of note that a compounded abrasive disc was markedly quieter than either steel blade due its inherent damping properties.

(Fig 4) indicates a spectrum of high levels between 250 Hz and 8 kHz for the conventional blade. The Laser-Q blade shows marked reductions between 2 kHz and 4 kHz with important resonances at 2.5 kHz and 8 kHz having been dampened out by the Laser treatment.

The most difficult materials to cut with this hand held saw were the concrete decorative bricks, this test showing a slight increase in noise levels by using the Laser-Q saw. It is difficult to comprehend that a saw identical in every way but with out the conventional ring of a normal saw could increase the noise level, at the worst assumption one would expect no change, but not an increase.

Non Ferrous Cutting

Only aluminium and brass sections were cut in these tests, a different set of treated and untreated blades of the same general dimensions had to be used. Thus results of the two materials are discussed separately.

1. Aluminium

These blades were run at 2880 rpm and each had 60 teeth giving a tooth passing frequency of 2.9 kHz. The rotational speed was taken from the machine specification, but the major peak at around 2 kHz seems to indicate the tooth passage frequency and must cast a doubt on the speed specification given with the machine.

The results from the tests on aluminium show poor reductions with a maximum of 1.5 dB(A) achieved by the Laser-Q blade (Fig 5). No explanation can be offered since in the previous tests had shown reductions of up to 6.1 dB(A) were achievable.

2. Brass

The brass cutting blades used in the tests had 96 teeth giving a tooth passage frequency of 4.6 kHz, but a very strong resonant frequency can also be seen in the results at about 2.5 kHz

The free running blade results shown in (Fig 6) show an incredible reduction using the Laser-Q blade of some 27 dB(A). When the untreated blade was switched on an extremely unpleasant whistle began to build up, reaching a crescendo within about 2 seconds. The sharp peak at 2 kHz is a positive resonance, possible enhanced by the fact that the tooth passage frequency is about double its value. The treated saw almost flattens the curve. The initial results caused the tests to be repeated several times, but still the results indicated this very good reduction.

(Fig 7) shows the same resonance when cutting a brass bar. It having the same dampening effect by using the treated blades. The overall reduction in level was 14 dB(A).

Discussion of results

The detailed series of noise tests were carried out by measuring the noise levels of both conventional and treated Laser-Q blades under various conditions. The materials used were various cross-section of wood, concrete, aluminium and brass.

The recorded noise levels varied as did the reductions achieved by using the treated blade. Apart from the treatment some or all of the following factors may have had an influence on the results.

a) Tooth/material interaction. In nearly all cases this gave rise to a clear 'tooth passage frequency' or 'TPF'.

b) Excitation of the blade by the teeth 'cutting' the air. In extreme cases this caused very high resonances to be built up within the blade.

c) Blade vibrations excited by either (a) or (b) above and/or other possible factors.

d) Workpiece vibration. Every care was taken to minimise these effects by, where possible, clamping the workpiece effectively.

e) External noise influences such as motor noise, extraction noise etc were not part of this study, but observation suggests these were relatively insignificant in the results of the tests.

Conclusions

In almost all of the tests using the untreated blades resonances were identifiable. The Laser-Q treated blades successfully flattened the spectral peaks produced by these resonances.

The reductions in noise level using the Laser-Q blade varied considerably with the type and cross section of the material being cut, but frequently they were better than 2 dB(A) with the exception figures of 10 dB(A) and even 25 dB(A). A few results showed a very small increase by using the treated blade. It is difficult to accept that an acoustically "dead" blade is noisier than one which has a clear "ring". But more controlled testing may identify the reasons why.

More research is needed to determine fully the mechanisms of resonance in circular saw blades and why not only this treatment but other "damping" treatment are effective. It may be possible to scientifically opitimise the design of the treatment to gain maximum noise reduction whilst retaining the structural integrity of the blade.

In terms of "pounds per dB(A)" with the cost of the treatment ranging from about £12 to £40, the treatment has got to be cost effective even with some of the small reductions measured. If it also gives the claimed cleaner and more efficient cut then the benefits have to be recognised. Add to this the advantage that the treatment can be given to any blade new or at a refurbishment stage the fitting of such a blade either on its own or as part of other noise control measures must be a serious consideration.

FIG. 1

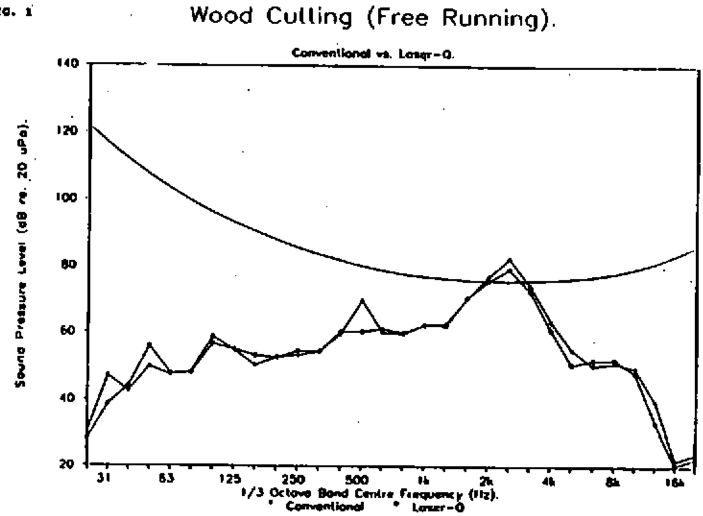
Wood Cutting (Free Running).
Conventional vs. Laser-O.
Sound Pressure Level (dB re. 20 uPa).
1/3 Octave Band Centre Frequency (Hz).
Conventional
Laser-O

FIG. 2

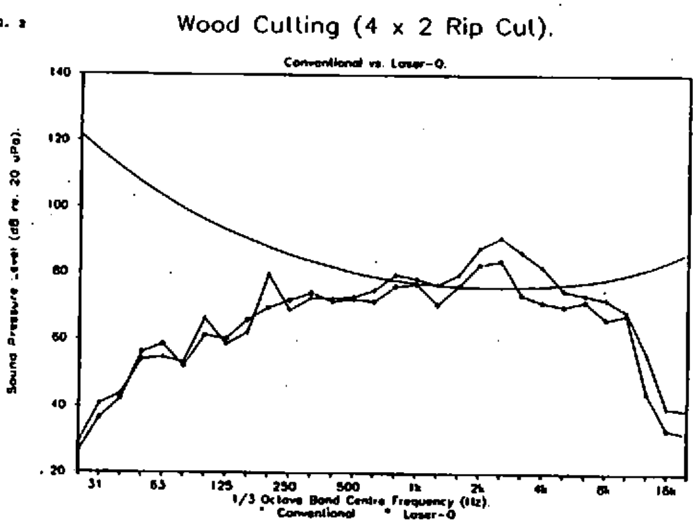
Wood Cutting (4 x 2 Rip Cut).
Conventional vs. Laser-O.
Sound Pressure Level (dB re. 20 uPa).
1/3 Octave Band Centre Frequency (Hz).
Conventional
Laser-O

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FIG. 3 Flag Cutting (Free Running).

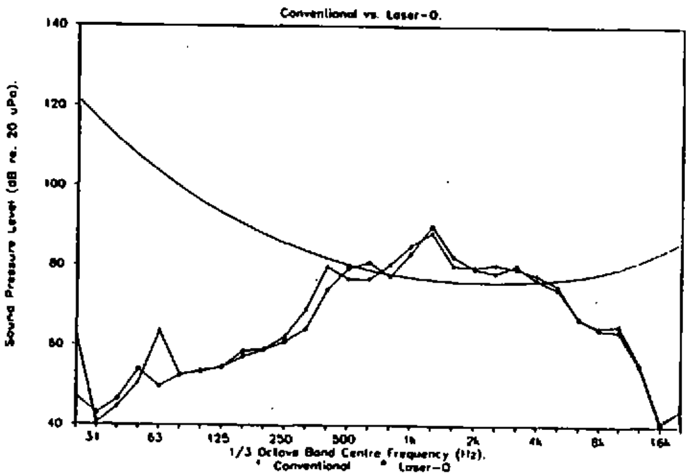

FIG. 4 Flag Cutting (600 x 600 x 35).

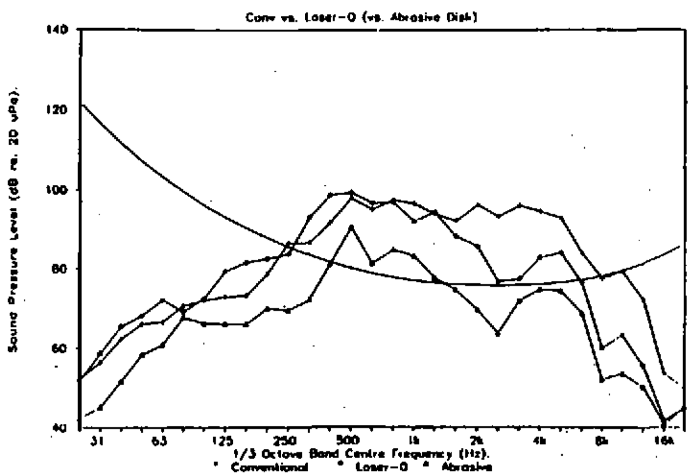

FIG. 5

Aluminium Cutting (50x50x5 Angle).

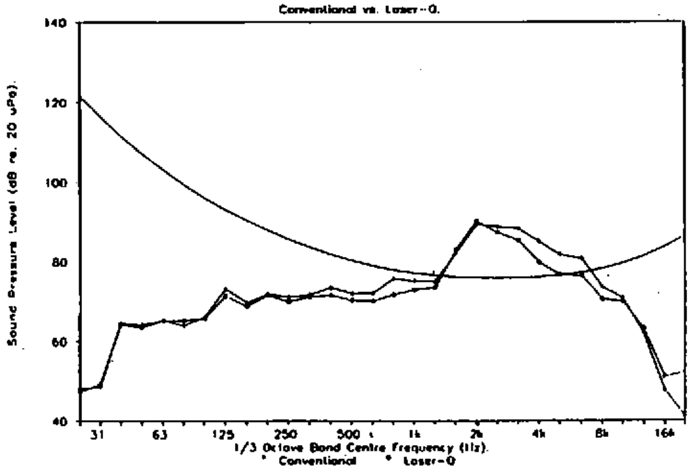

FIG. 6

Brass Cutting (Free Running).

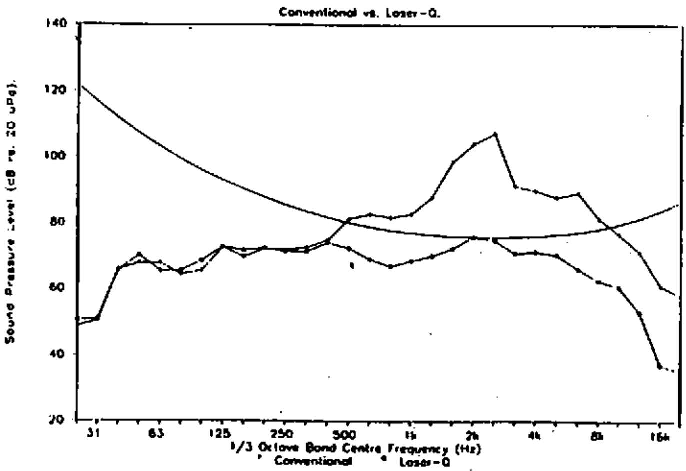

FIG. 7

Brass Cutting (25 x 5 mm Bar).