NOISE ANALYSIS OF AN INDUSTRIAL SEWING MACHINE.

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SUMMARY

This paper describes the analysis of noise generated by a high precision industrial sewing machine.
Various means were used in identifying the noise sources, two of the more novel techniques being the use of a video recorder; enabling the major sources to be determined, and the use of colour contour mapping; which highlighted an area not found by any other of the techniques used.
A key source of noise determined by the analysis was the needle transfer device, whose mechanism is described.

INTRODUCTION

In anticipation of impending noise legislation demands, the authors were approached by a company manufacturing a high precision industrial sewing machine with the task of measuring the noise levels, which were known to be high, and locating the major noise sources. This paper describes the methods used in identifying those noise sources.

DESCRIPTION OF THE MACHINE

The outward appearance was similar to other, more conventional machines. The operating mechanisms were very different, however, the sewing machine utilising a sophisticated needle transfer mechanism, operating at high speed, resulting in a unique and superior means of stitching garments.
Constructionally, the machine was mounted onto a sheet metal framework having full panels on the sides. The worktop consisted of a large plywood sheet, 4cm thick, having cut out sections to accommodate the top assembly. This worktop was capable of being lifted on hinges to facilitate maintenance and machine adjustments. The bulk of the operating mechanisms were mounted below this table, the exceptions being the upper needle bar and arm assembly and the cams and gearing associated with these mechanisms. These parts of the mechanism were supported by a large iron casting, the cams and gearing being located inside the casting and the needle bar and arm unit being mounted outside the casting, but inside a hinged cover. The cover served the dual purpose of maintaining safety when the machine was running and also reducing transmission of noise from this section of the machine.

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The needle transfer mechanisms were designed to operate on the impact forces generated by a pair of rocker arms, releasing and grasping the floating needle as it passed through the fabric and out the other side.
The top casting also housed the main control panel which was used to set the running speed and stitch length. The panel itself was made from acrylic and when held in place, covered a large opening in the top casting.
The main drive motor was housed at the rear of the machine, power transmission being achieved via a belt driven pulley system to the handwheel and main cam. These in turn rotated the gears which actuated the various mechanisms. The oscillating movement of the rocker arms was generated by the profile of the main cam located on the inner surface of the handwheel.

NOISE ANALYSIS

Because of the way in which the machine was constructed, it was felt that any noise produced would not radiate evenly, the work table, steel panels and other components tending to divide the output. This meant that the operator position would probably be subjected to a different noise level than would an observer standing some short distance away. Since machines of this nature are rarely used in isolation, it was felt that although noise produced from any one section of the machine may not affect the machine operator, it might affect an operator on an adjacent machine. It was therefore decided to measure noise both at the operator position and around the machine.

Initial Tests

As a first step, it was decided that a slow motion cine recording with sound would be made of the machine in operation. Each section of the mechanism would be analysed in turn and each particular visual picture tied in with the overall sound produced to isolate as many sources as possible. To test the feasibility of this approach, a normal speed video recording with sound was produced. This was done mainly to establish optimum camera angles, microphone positions and lighting. A video system was chosen in preference to cine since playback is instantaneous and any corrections or adjustments could be made and tried immediately. In the event, the video recording proved to be much more valuable than had been anticipated and plans to produce a slow motion cine film were abandoned. Although little qualitative information was gained from the video, close examination provided a direction to which the noise measurements could be concentrated.
Four distinct methods of analysis were conducted;
(i) colour contour mapping,
(ii) method of elimination,
(iii) narrow band analysis.
(iv) noise measurement at the operator position.

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Colour Contour Mapping.
In an attempt to gain an understanding of the overall sound pressure level for the machine, a colour contour map for the four sides of the machine were made. This type of technique is not new and has been used in both large and small scale applications [1,2]. The technique also has several serious limitations when used in this type of application, as detailed later.

Measurement Technique. Measurements were taken using a Cirrus Research sound level meter, with the scale set to slow, mounted onto an adjustable tripod. Graduated scales with 5cm steps were marked on the floor 25cm away from the baseline of the machine frame as shown in Figure 1. With the machine running at full speed, the SLM was 'scanned' across the machine in 5cm steps. After each pass, the SLM was raised by 5cm and the procedure repeated until a height of 130cm was attained. The whole process was repeated for the other three sides of the machine. No results were taken between floor level and 20cm high due to possible effects of plane wave relection and interference. Eventually, a 'sound picture' at 25cm from the machine was built up in 5cm squares. The results were tabulated and then plotted in a colour contour form to enable noise variations to be more easily defined. Figure 2 shows the colour contour map for the front of the machine. An interesting feature on this map was the area centred on the coordinates x=35cm, y=50cm. This showed the highest SPL (90.5dB(A)). By turning the handwheel slowly and listening in the outlined area, a small click could be heard. Further investigation revealed the cause to be a large cam striking a metal panel once per revolution of the handwheel. By pushing gently on the panel, the impact could be accentuated and by distorting the panel outwards, away from the cam, the impact could be eliminated. The SPL was taken again with the panel slightly distorted and was shown to be 88.5dB(A) at coordinate position x=35, y=50cm.

Method of Elimination.
The method of elimination required that the whole sewing machine be completely dismantled and the measurement of the noise level be taken as each of the suspected noise contributors were gradually added. Table 1 shows the results from these tests. It must be borne in mind whilst examining this table that the results are not true readings of the elements added, but are the results of combination or addition of several noise elements. The noise inducing elements were mainly reciprocating and interdependant. Thus, it was difficult to completely isolate one from another, with the result that the noise signature of each component had an influence on its neighbour. Nevertheless, it was possible to isolate a few of the noise contributors, namely;
(i) main gear assembly,
(ii) rocker arms assembly,
(iii needle bar assemblies.

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Sound measurements were made when these components had been isolated as far as was possible - ie the rest of the machine had been disabled - thereby permitting the actual noise level of the components to be recorded. The results of these tests are shown in Table 2.

Narrow Band Analysis.
A fundamental means of studying any noise is to analyse it's spectrum. This makes it possible to recognise the salient features or the signature of the noise. In this particular case, a single channel B&K Real Time Analyser, type 2033, was used. In order to determine the point at which the narrow band analysis commenced, a trigger was provided by mounting a reflective type of opto-electric device onto the worktop together with a white line painted onto the handwheel. The position of the line was of arbitrary but known position. Tests were performed both in the frequency and in the time domains. Typical results are shown in Figures 3 and 4 respectively. Figure 3 shows the frequency spectrum of the upper needle bar in a time window of 40ms centred on the upper needle bar take up position. Figure 4 shows the relative noise output in the time domain and clearly illustrates two peaks in each cycle of the machine. These correspond to the upper and lower needle bar impacts.

Noise Measurement at the Operator Position.
For these test, the machine was operated under normal working conditions at a number of speeds. The sound level meter was positioned at a position estimated to coincide with the ear of a machine operator. Figure 5 summarises the results obtained from this series of tests.

DISCUSSION

Although the results from the video film were purely qualitative, close up filming of the various sections of the mechanism indicated that the main sources were likely to be associated directly with the upper and lower needle bar assemblies. The sharp impact noises were narrowed down (by slowing the machine during filming) to the two needle bars at the moment that they hit their respective stops coinciding with the release of the needle from the needle bar assembly.
Figure 6 shows a section through one of the needle bar assemblies. The operating principle of the needle bar is one of impact of the inner spring loaded portion against the stop pin. The needle, which would be held in position with three ball bearings, is ejected from the needle bar on impact and caught by its duplicated needle bar on the opposite side of the material being sewn.
The colour contour mapping is a useful technique for visually identifying peak noise levels, but again is of a qualitative nature. It was clear, in this particular case, that a noise source other than those expected was present. This was

effectively a fault in the design of the machine. A panel was being struck by a cam enclosed within it. A simple modification solved this problem. A serious limitation of this technique was the time required to carry out a survey. Even though the resolution was low, a total of 1540 individual observation were made. More detailed investigations of this nature would require some form of computer plotting and possibly even traversing by robot.

The technique of progressively stripping the machine and taking noise measurements at each juncture clearly illustrated the contributions from each component. This is a fairly drastic technique, but for a product of this nature, identifying the noise sources from many dynamic linkages and cams is otherwise a difficult task.

The narrow band analysis provided a real indication of the severity of noise contribution from the two needle bar assemblies. It was obvious from the start that the noise was considerably greater when the machine was operated at high speed. Readings confirmed this. The operatives naturally used the machines at their fastest, because greater output, and therefore wages, would result.

CONCLUSIONS

The overall conclusions that can be inferred from the results can be summarised;

(i) at the operator position, the bulk of the noise received by the operator was found to be generated by the impact mechanism of the upper and lower needle bar assemblies,

(ii) the method of colour contour mapping was found to give highly satisfactory results, despite the limitations of this type of measurement procedure,

(iii) the noise analysis indicated a direction to which further work may be carried out in reducing the noise output from the machine.

References.

1. McNulty G J and Rosenhouse, 'Acoustic Design for the Layout of a Manufacturing Area'. Proc 17th International MTDR Conference, 1976.

2. McNulty G J, 'Contribution of Vibrating Machine Structures to Environmental Noise'. Symposium on Manufacturing Engineering,

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Table 1 Results of Isolation Tests.

Test	Description	SPL (dB(A))
1	Ambient	50
2	Motor on	59
3	Test result with only the following mechanisms in operation; motor, gear assy, rocker arm assembly	84
4	As 3, thread brush engaged	86
5	As 4, upper looper arm engaged	88
6	As 5, cam followers engaged	89
7	As 6, clamp finger in place	89
8	As 7, opener cams located	89.5
9	As 7, lower looper arm engaged	91
10	As 9, pressure foot engaged	92.5
11	As 10, pressure foot follower in operation (with cloth)	93
12	As 11, both needle bars installed	93.5

Table 2 Further Isolation Tests

Test	Description	SPL (dB(A))
1	Ambient	44
2	Motor on	54
3	Main gear engaged	74
4	As 3, with thread brush	80.5
5	Ambient	42
6	Motor on	51
7	Rocker arm assembly engaged	78
8	As 7, thread brush engaged	82.5
9	Ambient	47
10	Motor on	54.5
11	Rocker arms and needle bars	89.5

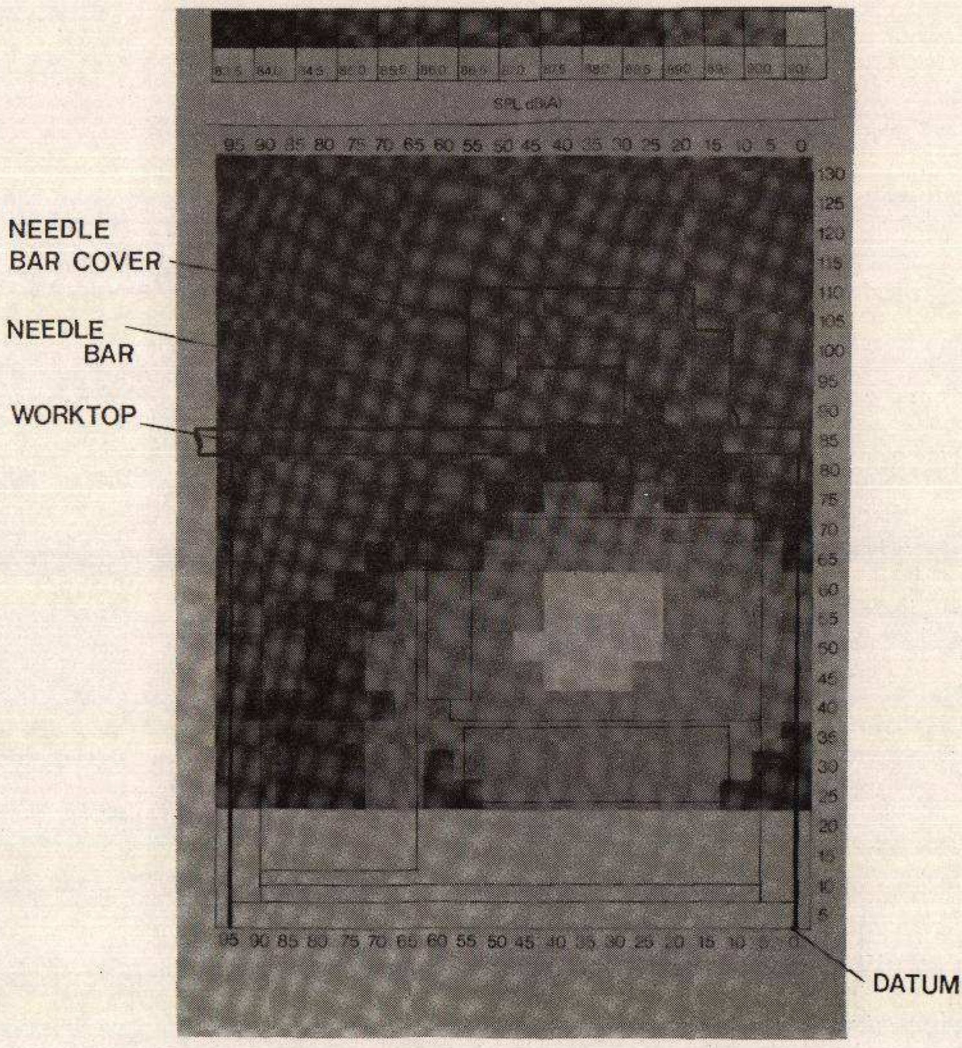

Figure 2. Colour Contour map of the Front of the Machine

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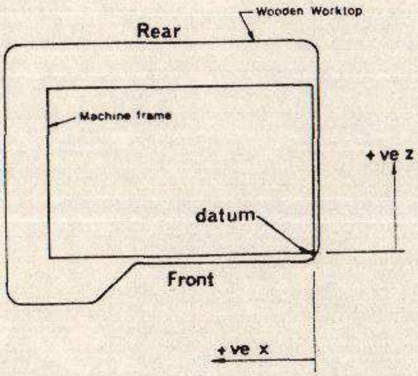

Figure 1. Details of Datum Point & Views on Machine

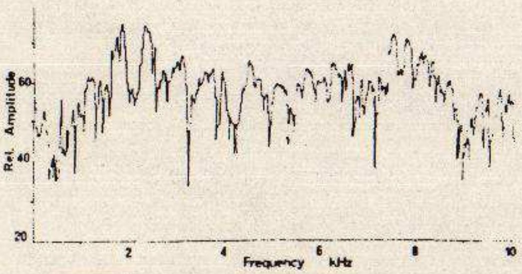

Figure 3. Frequency Analysis of Upper Needle Bar - 40ms window

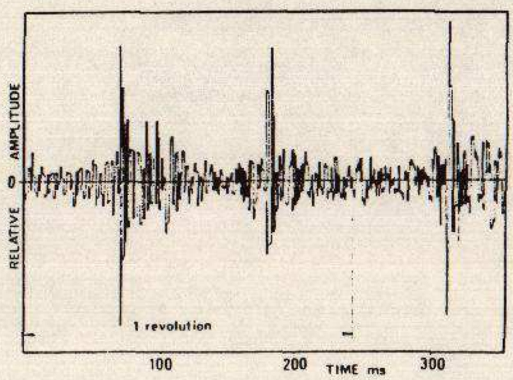

Figure 4. Noise Output from Upper Needle Bar - Time Domain

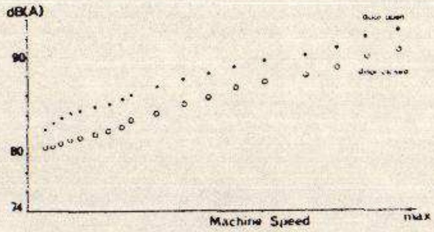

Figure 5. Noise Output at Operator Position

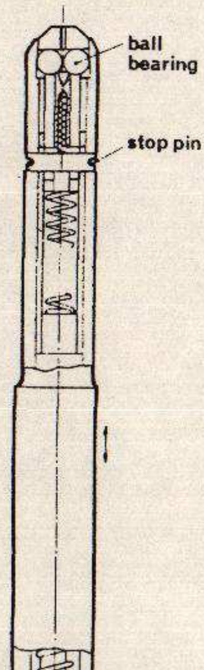

Figure 6. Needle Bar Assembly