THE SPRING RESEARCH & MANUFACTURERS' ASSOCIATION

END GRINDING OF SPRINGS

Progress Report No. 2

by

M.R. Southward B.Sc.

Report No. 262

May 1976

THE SPRING RESEARCH & MANUFACTURERS' ASSOCIATION

Report No. 262

END GRINDING OF SPRINGS

Progress Report No. 2

SUMMARY

The previous progress report on this topic(1) highlighted the difficulties involved in assessing grinding wheel performance and indicated the form future work should take. This investigation follows the lines suggested, using a spring design of smaller wire diameter. To ensure compatability with the previous work, a Bennett SG1-14 Spring End Grinder was employed.

Springs of the same design were ground, using different grade wheels at various grinding speeds. Measurements of wheels and springs were taken during the process and the machine adjusted, if necessary, to keep the ground springs within the free length specification. To decide when grinding should cease, two parameters were chosen, one of which put a limit on the spreading of the end coils whilst the other placed a limit upon the discoloration of the end coils.

Data have been produced for a typical spring design, with regard to metal removal/grit removal ratios and the cost of the grinding operation, that can be used as a standard for the process.

May 1976

CONTENTS

CONTENTS (Cont.)

Report No. 262

END GRINDING OF SPRINGS

Progress Report No. 2

by

M.R. Southward, B.Sc.

1. INTRODUCTION

This is the second report in a long-term programme of investigations into the many variables encountered in the end grinding of springs. The aim of the programme is to produce guidelines for the determination of optimum grinding parameters for springs of known design and material. In determining the effect of wheel grade and grinding speed on the wheel wear and number of springs that can be ground, the procedure followed was the same as in previous investigations. In addition, the overall cost of grinding a batch of springs has been assessed. The results presented show the effect of the grinding variables investigated in a graphical form.

2. EQUIPMENT

The work was carried out on a similar grinding machine to that used previously, a Bennett SG1-14 spring end grinder. The variable speed rotating table contained 40 bushes, enabling rates of grinding between 12 and 120 springs per minute to be selected.

The grinding wheels were 355 mm in diameter, running horizontally at a constant speed of 1700 rpm. Three types of wheel were used, all of the MA24 type but varying in hardness: Grade L the softest wheel, Grade M and Grade N, the hardest wheel. Attached to the grinder was a D.C.E.

Dust Extractor Unit, which was in continuous operation while the springs were being ground.

3. SPRING DESIGN

The springs used for this investigation were of a smaller wire diameter than those used previously, enabling the ends to be ground in one pass without excessive wear of the wheels. Details of the spring design used are given below:-

Wire Diameter (mm)	2.03
Mean Coil Diameter (mm)	12.7
Total Coils	6.0
Active Coils	4.0
Free Length (after grinding) (mm)	20.32 ± 0.43
Weight of Unground Spring (grammes)	5.14

4. PROCEDURE

4.1 Parameters

Before grinding was begun, various parameters were fixed which would determine the point at which grinding would be stopped.

The first parameter was the spreading of the end coils. As a quick method of determining when this occurred, a gauge was made which consisted of 25 mm long cylinder, the diameter of the hole being 0.15 mm larger than the mean outside diameter of the springs. By passing the last 25 consecutive springs of every 50 through this gauge, it acted on a "Go/No-Go" principle. When the "No-Go" reached a pre-determined level of 20%, grinding was stopped.

The other parameter concerned the discoloration of the end coils that occurs as debris collects in the wheels. Initially the end coil begins to turn brown near the tip, then changes to blue and the discoloration spreads further round the coil as grinding continues. It was decided to stop grinding when the blue discoloration covered approximately one quarter of the coil.

4.2 Grinding Procedure

Once the wheels were attached in position, they were dressed level and weighed. The gap between the wheels was then adjusted so as to produce a spring of the required dimensions meeting the BS 1726 class B tolerance for end squareness for the table speed selected.

A batch of springs of known weight was ground and the free length was recorded after every 50 springs, the machine being adjusted if necessary to maintain the required free length. In addition, springs were checked for spreading of the end coils and discolouration, as described in section 4.1. On completion of the batch, the springs were reweighed and the amount of metal removed determined. Similarly the wheels were removed and weighed, after their profiles had been measured. The latter was performed by traversing a dial gauge along the radius of the wheel and recording the readings at 6mm intervals. The average readings obtained from three radii on each wheel were calculated and the wheel profiles constructed. The wheels were then replaced in position and the next batch of springs ground. This procedure was repeated until cessation of grinding; the wheels were then measured and redressed square. This procedure was performed for each wheel in the following sequence.

Wheel Type	Table Speed rpm	Grinding Rate (springs/min.)
L	1.0	40
L	0.75	30
M	1.25	50
M	1.0	40
M	0.75	30
M	0.5	20
N	1.25	50
N	1.0	40
N	0.75	30
N	0.5	20

5. RESULTS

The amount of metal removed on grinding depended on the variation in length of the unground springs, since the variation in free length after grinding was closely controlled. To determine the variation in unground springs, the overall length of a sample of 30 from each of 4 different sacks was taken, the results being shown below:

Sack No.	Average Free Length (mm)	Range (mm)
1	23.17	0.94
2	23.10	0.69
3	23.06	0.99
4	23.02	0.74

The average spring free length was 23.08 mm and the range over the entire 120 springs was 1.14 mm.

Thus, although the weight of the springs before grinding was consistent, the weight of metal removed per spring varied from batch to batch because of the difference in the thickness of the end coil which had to be removed to obtain the same free length. Weighing batches of springs before and after grinding showed that the average metal removal rate was 0.37 grammes/spring, although there was considerable variation from batch to batch.

The amount of grit removed from the wheels for each of these batches is shown in Table I; the ratio of metal removal/wheel wear has been calculated and is recorded in Table II, which enables an easy comparison to be made between the various wheels and table speeds.

Table III is a summary of the wheel performances; giving the maximum number of springs ground, the metal removal/

wheel wear ratio after the wheels had been redressed and the total wear of the two wheels at their outside edge. This last value, which is an indication of the amount of wheel removed on dressing, was determined from the wheel profiles. The wheel profiles were drawn for each batch of springs and each combination of wheel and table speed; for simplicity however, only three figures are included in this report, Figs. 1 to 3, which relate to each of the three wheels at a grinding rate of 30 springs/min.

6. DISCUSSION

6.1 Effect of Table Speed

Starting with a grinding rate of 50 springs/min., it was found that a reduction in this speed increased the number of springs that could be ground within the parameters, the wheel type having little effect on this value. The actual values for the maximum number of springs ground for each combination of wheel and table speed can be found in Table III. The reason for cessation of grinding was excessive discoloration of the end coils in all cases except for the lowest table speed with either the M or N Grade wheels. In these two cases, excessive spreading of the end coils occurred, preventing springs from passing through the gauge.

At the fastest grinding speed with the Grade N wheel, discoloration of the springs occurred after 1200 springs and excessive spreading after 1350 springs. Using the softer Grade M wheel, however, though discoloration occurred at about the same point (after 1225 springs), spreading of the end coils did not take place until about 2500 springs had been ground. It would appear that, because of the nature of the assessment of an unacceptable spring, a greater variation in the number of springs that can be ground is encountered with the softer wheel; this may affect the cost evaluation technique described in Section 6.3.

6.2 Effect of Wheels

Table I shows the amount of wheel removed on grinding each batch of springs and the weight of wheel removed after dressing is shown in Table III. The general trend indicated is that the softer the wheel, the more grit is removed on grinding but the less is removed on dressing. The underlying reason can be seen from Figs. 1 to 3, which show the wheel profiles after each batch of springs has been ground: in the case of the softest wheel, grit is removed much closer to the centre of the wheel.

The ratio of metal removal to wheel wear is recorded in Table II, which gives an indication of the efficiency of the grinding for each specific wheel and table speed combination. The harder the wheel or the slower the grinding rate, the more efficient is the process.

The wheel wear is greatest while the first batch of springs is being ground where the edge of the wheel is being rounded, the metal/wheel removal ratio being about 1:1. As the wheel wears, the rate of wheel wear falls but generally the average ratio of metal/wheel removal is between 2:1 and 4:1. When the amount of wheel removed after dressing is accounted for, the efficiency of the grinding process falls drastically, the average metal/wheel removal ratio being less than 1:1.

It is interesting to note that table speed does not affect the total wheel wear at the edge and that the type of wheel may also have a negligible effect. The reason for this can be seen from the wheel profiles: the top wheel profile shows a levelling off at the edge, that is to say, no more was removed from the edge after the first few batches. This point is reached when the distance between the wheels plus the wear at the edges of the wheels approximates to the free length of the spring prior to grinding. This value of wheel wear is critical as it governs the figure for the amount of wheel used in the grinding cost analysis.

6.3 Comparative Grinding Costs

In order to determine the comparative grinding costs for the various wheel and table speed combinations, approximate costs are detailed below:

Number of springs to be ground	5000
Time to dress and reset wheel	0.25 hour
Cost of wheels per set	£31.50
Cost of wheel per mm of usable depth	£0.31
Cost of labour + overheads	£2.70 per hour
Cost of machine depreciation*	£0.45 per hour
Cost of power consumption	£0.08 per hour
Total operation cost	£3.23 per hour

*This applies to the grinding machine and dust extractor plus maintenance costs.

The figure for overheads includes administration costs, depreciation of buildings, heating and lighting, and cost of floor space.

The total operation cost figure is applicable only to this investigation; each individual needs to do his own costing as it can have a significant effect on the final cost curve. Each company's costing will vary according to whether the grinder had an automatic feed mechanism and whether different grades of labour are used for loading the machine and dressing the wheels.

Using these cost data in conjunction with the data given in Table III, the total time to grind 5000 springs can be calculated, as tabulated in Table IV.

Multiplying this time by the operation cost factor and adding the cost of wheel used will give the total grinding cost (see Table VI). Using these data, cost curves have been plotted for Grade M and N wheels (Figs. 4 and 5); these give an indication of the wheel and table speed combination for the most economical grinding of this spring design. A Grade N wheel is the most economical of those investigated, with the possibility that a harder wheel may be even better, depending upon whether the N grade wheel is at the minimum point of the wheel cost curve. The most economical grinding rate is 32.5 springs/min., as far as this investigation is concerned.

As mentioned previously, the operation cost factor is critical as an increase in this will increase the gradient of the operation cost line, thus increasing the table speed to be maintained at the minimum point of the total cost curve.

6.4 General Discussion

The parameters used to decide when grinding must cease were satisfactory to some extent but were difficult to apply with accuracy. When a few springs all near the top limit of their free length tolerance were ground, they exceeded the grinding parameters, thus giving a false impression, as the great majority of springs was correctly ground. To determine if a false indication was being given, grinding was continued after the parameters had been exceeded to establish whether a general pattern was occurring.

As mentioned in Section 6.2, the wheel profiles show that the actual grinding area on the wheels moves near to the centre of the wheel during grinding. Since the wheels rotate at a constant speed, the actual cutting grit is decreasing in velocity as the spring nears the centre of the wheel. It is possible therefore, that an increase in wheel speed would increase the number of springs that can be successfully ground.

7. CONCLUSIONS

This project has provided an estimate of the most economical wheel and table speed combination for grinding one particular spring design. By retaining the same design, other variables such as wheel composition and speed can be investigated and compared with the conventional methods. Later, different spring materials and designs may be investigated to give a fuller understanding of the economics of end grinding.

8. REFERENCE

1. BIRD G.C. "End Grinding of Springs: Progress Report No. 1". SRA Report No. 237

9. ACKNOWLEDGEMENTS

The Association would like to thank the following Member Companies for their invaluable assistance in the project:

Abrasive Products Limited
Bennett Tools Limited
Geo. Salter and Co. Limited.

TABLE I RATE OF WHEEL WEAR (g/spring)

WHEEL L

	GRINDING RATE (springs/min)			
		40	30	
1 - 500		) 0.328	0.504	
501 - 1000		)	0.188	
1001 - 1500		0.113	0.104	
1501 - 2000		0.122	0.088	
2001 - 2500			0.102	

WHEEL M

	GRINDING RATE (springs/min)			
	50	40	30	20
1 - 500	0.354	0.390	0.504	0.376
501 - 1000	0.078	0.132	0.188	) 0.122
1001 - 1500	0.154	0.154	0.124	)
1501 - 2000			0.088	) 0.036
2001 - 2500			0.102	)
2501 - 3000			0.056	) 0.054
3001 - 3500				)
3501 - 4000				) 0.052
4001 - 4500				)
4501 - 4850				0.091

WHEEL N

	GRINDING RATE (springs/min)			
	50	40	30	20
1 - 500	0.392	0.290	0.332	0.264
501 - 1000	0.124	0.168	0.134	0.200
1001 - 1500	0.046	0.106	0.096	) 0.083
1501 - 2000		0.100	0.152	)
2001 - 2500			0.034	) 0.058
2501 - 3000			0.060	)
3001 - 3500				) 0.062
3501 - 4000				)
4001 - 4500				) 0.031
4501 - 5000				)
5001 - 5500				0.098

TABLE II RATIO METAL REMOVAL/WHEEL WEAR

WHEEL L

	GRINDING RATE (springs/min)			
		40	30	
1 - 500		1.1	0.7	
501 - 1000			2.0	
1001 - 1500		3.3	3.6	
1501 - 2000		3.0	4.2	
2001 - 2500			3.6	
Average		1.7	2.1	

WHEEL M

	GRINDING RATE (springs/min)			
	50	40	30	20
1 - 500	1.0	0.9	0.7	1.0
501 - 1000	4.7	2.8	2.0	3.0
1001 - 1500	2.4	2.4	3.0	
1501 - 2000			4.2	10.3
2001 - 2500			3.6	
2501 - 3000			6.6	6.9
3001 - 3500				
3501 - 4000				7.1
4001 - 4500				
4501 - 4850				4.0
Average	2.1	1.8	2.0	3.5

WHEEL N

	GRINDING RATE (springs/min)			
	50	40	30	20
1 - 500	0.9	1.3	1.1	1.4
501 - 1000	3.0	2.2	2.8	1.9
1001 - 1500	8.0	3.5	3.9	4.4
1501 - 2000		3.7	2.4	
2001 - 2500			10.9	6.4
2501 - 3000			6.2	
3001 - 3500				6.0
3501 - 4000				
4001 - 4500				12.0
4501 - 5000				
5001 - 5500				3.8
Average	1.9	2.6	3.1	4.0

TABLE III SUMMARY OF WHEEL PERFORMANCE DATA

WHEEL GRADE	GRINDING RATE (springs/min)	MAX NO. OF SPRINGS GROUND	WT. OF WHEEL REMOVED DURING GRINDING (g)	WT. REMOVED DURING DRESSING (g)	OVERALL METAL REMOVAL/ WHEEL WEAR RATIO	TOTAL WHEEL WEAR AT EDGE (mm)
L	40	1700	440	1270	0.4	4.45
L	30	2200	490	670	0.8	4.45
M	50	1225	290	590	0.6	4.06
M	40	1500	340	890	0.5	3.84
M	30	2500	530	670	0.8	3.84
M	20	4850	480	570	1.7	3.81
N	50	1200	280	800	0.5	3.81
N	40	1700	290	930	0.6	3.89
N	30	3000	400	910	0.8	3.89
N	20	5500	510	570	1.9	3.89

TABLE IV ANALYSIS OF GRINDING TIME

WHEEL GRADE	GRINDING RATE (springs/ min)	NO. OF DRESSING OPERATIONS	DRESSING TIME (h)	GRINDING TIME (h)	TOTAL TIME (h)
L	40	2.94	0.74	2.08	2.82
L	30	2.27	0.57	2.78	3.35
M	50	4.08	1.04	1.39	2.43
M	40	3.33	0.83	2.08	2.91
M	30	2.00	0.50	2.78	3.28
M	20	1.03	0.26	4.17	4.43
N	50	4.17	1.04	1.39	2.43
N	40	2.94	0.74	2.08	2.82
N	30	1.67	0.42	2.78	3.20
N	20	0.91	0.23	4.17	4.40

TABLE V BREAKDOWN OF GRINDING COSTS

WHEEL GRADE	GRINDING RATE (springs/ min)	COST OF GRINDING TIME (£)	COST OF WHEEL USED (£)	TOTAL COST (£)
L	40	9.11	4.06	13.17
L	30	10.82	3.14	13.96
M	50	7.85	5.13	12.98
M	40	9.40	3.97	13.37
M	30	10.59	2.38	12.97
M	20	14.31	1.22	15.53
N	50	7.85	4.70	12.55
N	40	9.11	3.56	12.67
N	30	10.34	2.01	12.35
N	20	14.21	1.10	15.31

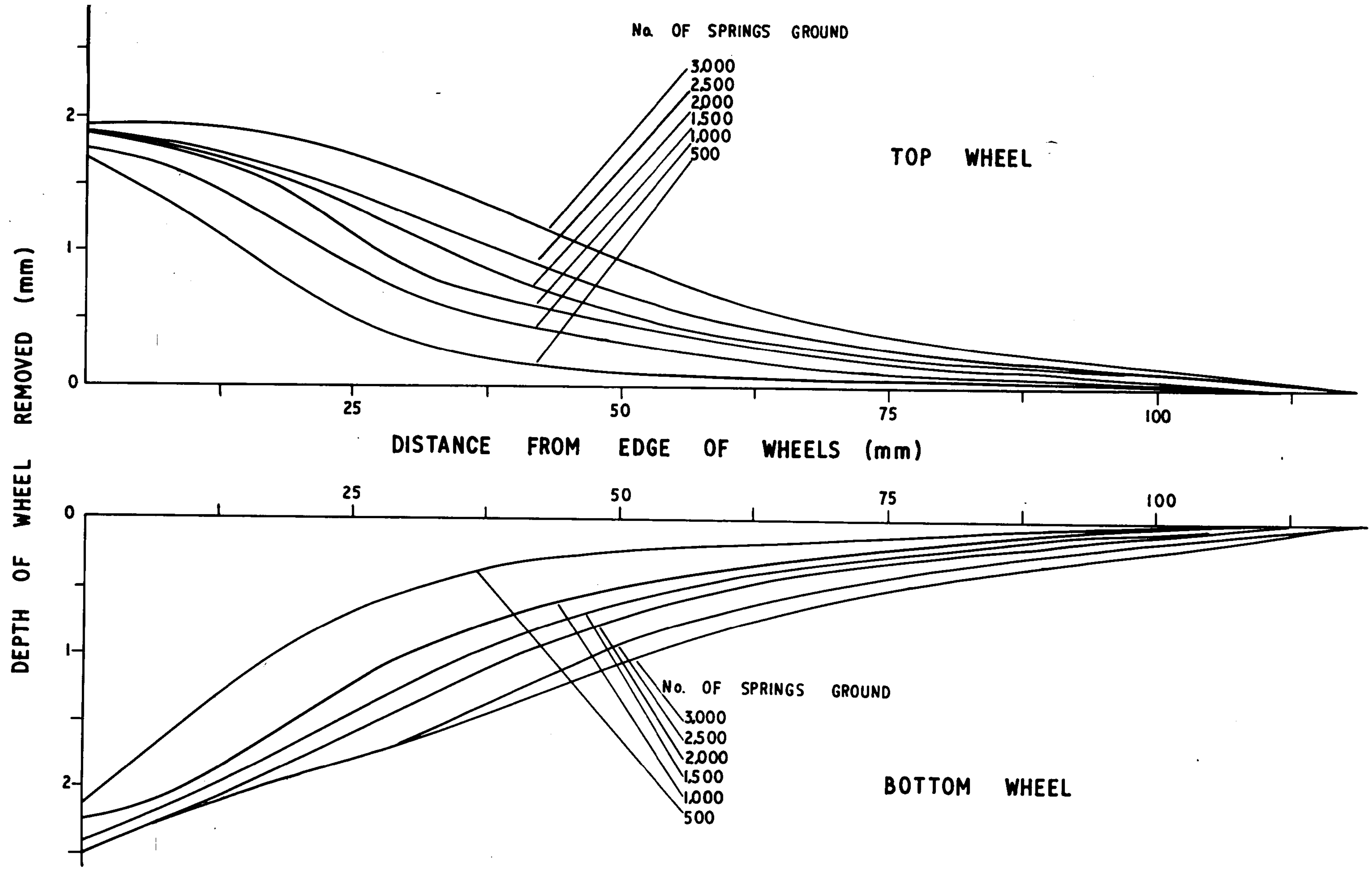

FIG. I PROFILES OF TOP AND BOTTOM GRADE L WHEELS FOR A GRINDING RATE OF 30 SPRINGS/min.

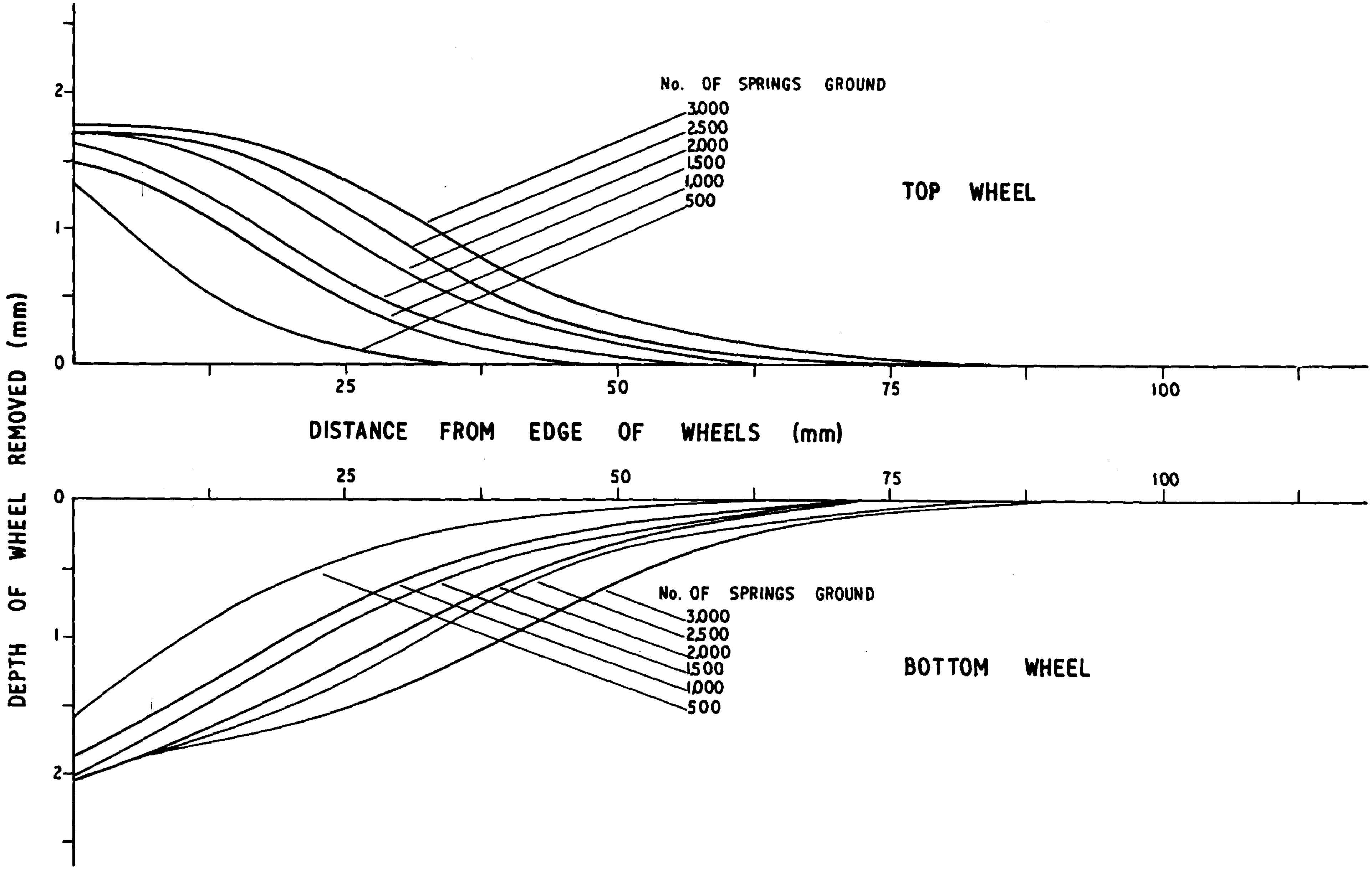

FIG. 2 PROFILES OF TOP AND BOTTOM GRADE M WHEELS FOR A GRINDING RATE OF 30 SPRINGS / min.

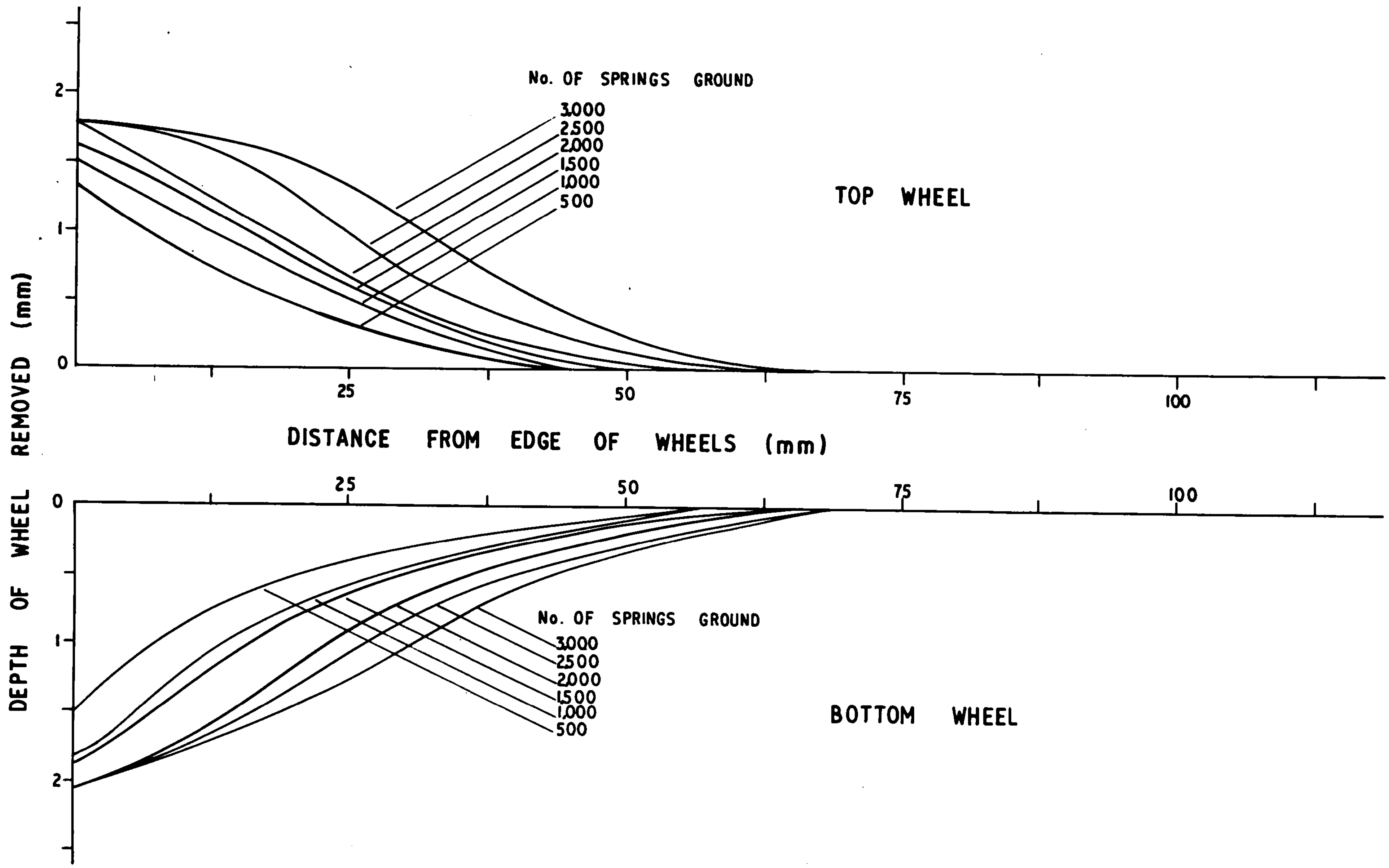

FIG. 3 PROFILES OF TOP AND BOTTOM GRADE N WHEELS FOR A GRINDING RATE OF 30 SPRINGS /min.

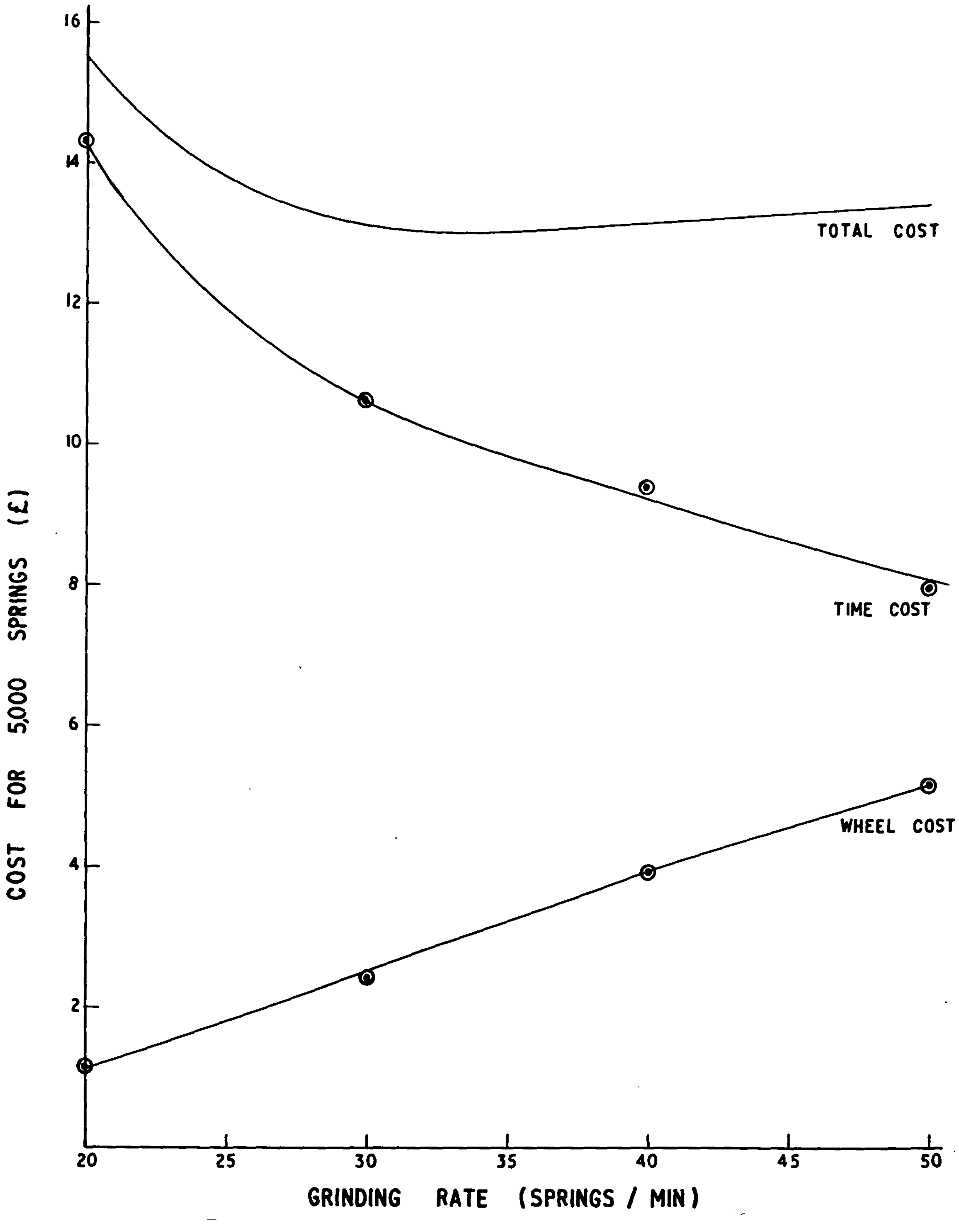

FIG. 4 COST CURVES FOR GRADE M WHEELS.

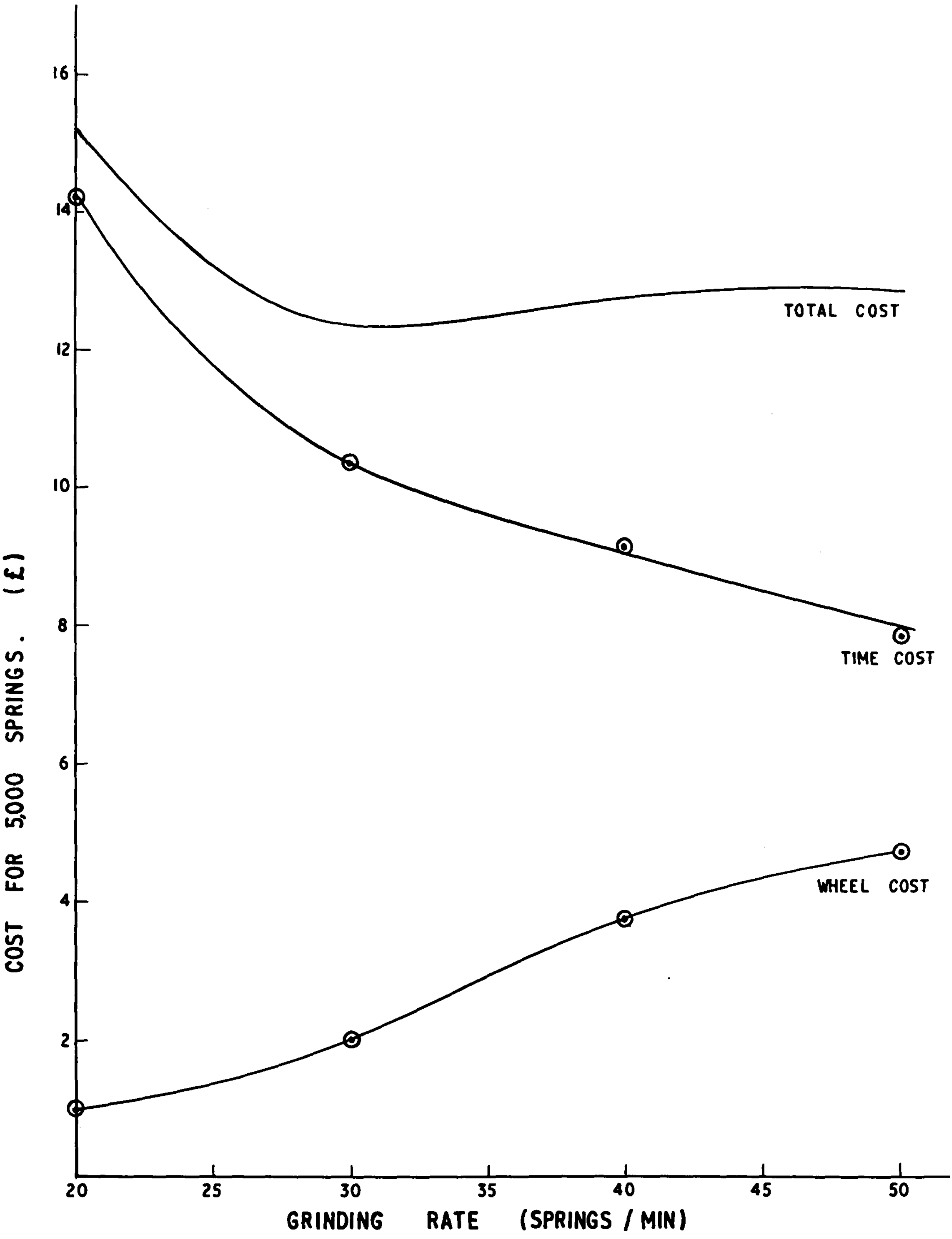

FIG. 5 COST CURVES FOR GRADE N WHEEL