

SHIPBUILDERS: SAMPLE

NEWBUILDINGS: SAMPLE

TORSIONAL VIBRATION ANALYSIS OF THE PROPULSION SYSTEM

REPORT: TVC 000-1.00

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Signature: _____

Date: 2002-09-21

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MACHINERY PARTICULARS

GENERAL DATA

Ship's name	Sample
Newbuilding No.	Sample
Description	Sample
Classification	Sample
Class	Sample
Shipbuilders	Sample
Enginebuilders	Sample
Description of machinery ..	Direct coupled FP propeller is driven by the low speed engine through the shafting

ENGINE DATA

Engine No.	Sample
Engine type	Sample 2-stroke diesel engine
Cycle	2
Number of cylinders	6
Bore	600 mm
Stroke	2400 mm
Firing order	1-5-3-4-2-6
Maximum pressure	15.0 MPa
Mean ind. pressure/MCR	2.00 MPa
Max. continuous output	13530 kW
Max. continuous speed	105 rpm
Idling speed	20 rpm
Span of bearings	1020 mm
Diameter of bearings	720 mm
Inertia of flywheel	13500 kgm ²
Crankshaft Plan No.	Sample
Exc. components data	Sample

PROPELLER DATA

Propeller builder	Sample
Propeller Plan No.	Sample
Type	Fixed pitch
No. of blades	4
Diameter	6900 mm
Pitch at 0.7D	5237 mm
Area ratio	0.58
Inertia (dry)	50799 kgm ²
Inertia (in water)	64438 kgm ²
Mass	23904 kg

SHAFTING DATA

Shafting builder	Sample
Shafting Plan No.	Sample
Intermediate shaft material	Forged steel, UTS = 600 N/mm ²
Intermediate shaft diameter	510 mm
Propeller shaft material ..	Forged steel, UTS = 600 N/mm ²
Propeller shaft diameter ..	565 mm
Overall length	14921 mm
Overall mass	22922 kg

GEARING DATA

Make and type	No gearing
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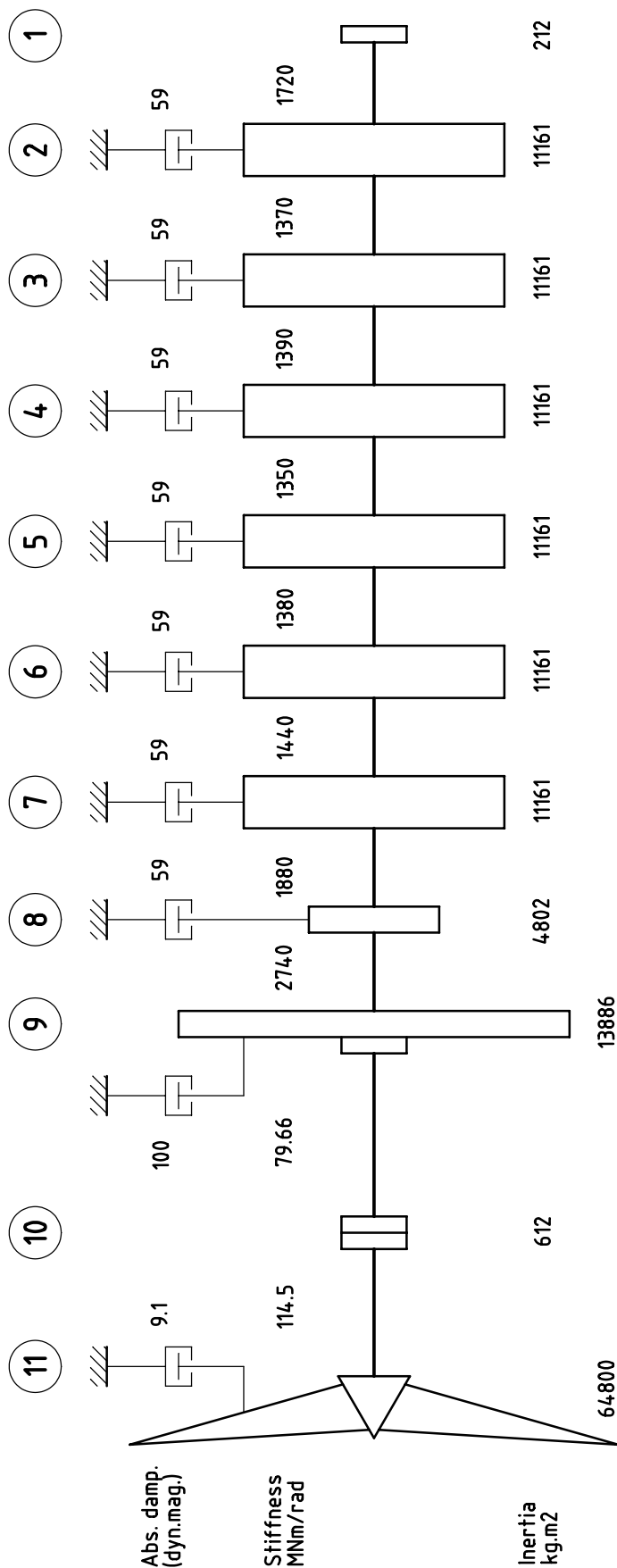
VIBRATION DAMPER DATA

Make and type	No vibration damper
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CLUTCH DATA

Make and type	No clutch
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TORSIONAL SCHEME (see Page 5)



P+W = 64438
PS+PC = 362
FW = 13500 CD = 3608
IS = 386 MC = 1194

LEGEND:

- P+W Propeller + added water
- PS Propeller shaft
- PC Propeller cap
- FW Turning wheel
- CD Camshaft drive + thrust cam
- IS Intermediate shaft
- MC Moment compensator
- 1 Flange
- 2 Cylinder No. 1
- 3 Cylinder No. 2
- 4 Cylinder No. 3
- 5 Cylinder No. 4
- 6 Cylinder No. 5
- 7 Cylinder No. 6
- 8 Camshaft drive
- 9 Turning wheel
- 10 Flange
- 11 Propeller+AW

**SAMPLE
TVC 000-1.00
TORSIONAL SCHEME OF THE SYSTEM**

CONCLUSIONS

Satisfactory torsional vibration behavior has been found in the whole speed range between 20 engine rpm and 105 engine rpm (+5%). Operation limits:

- Normal operation:

Engine speed range between 50 rpm and 61 rpm is to be avoided due to the I-node, 6th order torsional critical.

- Misfiring operation:

In the event of one cylinder misfiring the maximum engine speed is not to exceed 77 rpm due to the I-node, 4th order critical.

NOTES

Above conclusions are based on the following calculations:

- Undamped natural vibration calculation for the first two natural modes,
- Damped forced vibration calculation for the engine normal operation, as well as six separate misfiring cylinder calculations. (Note that the results of one misfiring cylinder case only, Cylinder No.3 misfiring, are enclosed herein.)

Forced vibration calculation results, shown in the enclosed diagrams, are obtained by the synthesis of 20 single order responses.

CALCULATION DATA

ENGINE DATA

Engine type	Sample
Cycle	2
Number of cylinders	6
Firing order	1-5-3-4-2-6
Piston diameter	600.0 mm
Crank pin radius	1200.0 mm
Connecting rod length	2460.0 mm
Oscillating mass/cyl.	5003.0 kg
Minimum engine speed	20.0 rpm
Engine speed at MCR	105.0 rpm
Mean ind. pressure at MCR	2.0 MPa

TORSIONAL MODEL DATA

No	Element	Mass inertia kgm ²	Shaft stiffness Nm/rad	Calc. diameter mm	Abs. damping Dyn.mag.
1	FLANGE	212.0	1720.0E6	719.8	-
2	CYLINDER NO. 1	11161.0	1370.0E6	719.8	59.0
3	CYLINDER NO. 2	11161.0	1390.0E6	719.8	59.0
4	CYLINDER NO. 3	11161.0	1350.0E6	719.8	59.0
5	CYLINDER NO. 4	11161.0	1380.0E6	719.8	59.0
6	CYLINDER NO. 5	11161.0	1440.0E6	719.8	59.0
7	CYLINDER NO. 6	11161.0	1880.0E6	719.8	59.0
8	CAMSHAFT DRIVE	4802.0	2740.0E6	719.8	59.0
9	TURNING WHEEL	13886.0	79.66E6	510.0	100.0
10	FLANGE	612.0	114.5E6	565.0	-
11	PROPELLER+AW	64800.0	-	-	9.1

MATERIAL PROPERTIES (min. UTS)

Crankshaft	610.0 N/mm ²
Intermediate shaft	600.0 N/mm ²
Propeller shaft	600.0 N/mm ²

CALCULATION RESULTS

NATURAL VIBRATIONS

Main resonance (I/6)	55.1	rpm
Second main resonance (I/4)	82.6	rpm

FORCED VIBRATIONS, NORMAL OPERATION

Barred speed range, lower bound	50.4	rpm
Barred speed range, upper bound	60.2	rpm
Crankshaft peak torque, I/6, synthesis	2133.4	kNm
Crankshaft peak stress, I/6, synthesis	29.1	N/mm ²
Crankshaft peak stress, I/6, 6th order	28.9	N/mm ²
Intermediate shaft peak torque, I/6, synthesis	2476.7	kNm
Intermediate shaft peak stress, I/6, synthesis	95.0	N/mm ²
Intermediate shaft peak stress, I/6, 6th order	94.5	N/mm ²
Propeller shaft peak torque, I/6, synthesis .	2469.3	kNm
Propeller shaft peak stress, I/6, synthesis .	69.7	N/mm ²
Propeller shaft peak stress, I/6, 6th order .	69.3	N/mm ²

FORCED VIBRATIONS, ONE CYLINDER MISFIRING

Engine maximum speed	77.0	rpm
Crankshaft peak torque, I/6, synthesis	2278.0	kNm
Crankshaft peak stress, I/6, synthesis	31.1	N/mm ²
Crankshaft peak stress, I/6, 6th order	30.0	N/mm ²
Intermediate shaft peak torque, I/6, synthesis	2640.5	kNm
Intermediate shaft peak stress, I/6, synthesis	101.4	N/mm ²
Intermediate shaft peak stress, I/6, 6th order	98.2	N/mm ²
Propeller shaft peak torque, I/6, synthesis .	2632.5	kNm
Propeller shaft peak stress, I/6, synthesis .	74.3	N/mm ²
Propeller shaft peak stress, I/6, 6th order .	72.0	N/mm ²
Crankshaft peak torque, I/4, synthesis	1244.5	kNm
Crankshaft peak stress, I/4, synthesis	17.0	N/mm ²
Crankshaft peak stress, I/4, 4th order	9.5	N/mm ²
Intermediate shaft peak torque, I/4, synthesis	1204.8	kNm
Intermediate shaft peak stress, I/4, synthesis	46.3	N/mm ²
Intermediate shaft peak stress, I/4, 4th order	34.3	N/mm ²
Propeller shaft peak torque, I/4, synthesis .	1201.4	kNm
Propeller shaft peak stress, I/4, synthesis .	33.9	N/mm ²
Propeller shaft peak stress, I/4, 4th order .	25.2	N/mm ²

NATURAL VIBRATIONS

Natural mode 1
 Natural frequency 330.436 cpm

No	Element	Rel. ampl. rad	Torque Nm
1	FLANGE	1.00000	0.25385E+06
2	CYLINDER NO. 1	0.99985	0.13616E+08
3	CYLINDER NO. 2	0.98991	0.26845E+08
4	CYLINDER NO. 3	0.97060	0.39816E+08
5	CYLINDER NO. 4	0.94111	0.52393E+08
6	CYLINDER NO. 5	0.90314	0.64463E+08
7	CYLINDER NO. 6	0.85838	0.75934E+08
8	CAMSHAFT DRIVE	0.81799	0.80637E+08
9	TURNING WHEEL	0.78856	0.93748E+08
10	FLANGE	-0.38830	0.93464E+08
11	PROPELLER+AW	-1.20458	

Critical Speeds

Vector sum rad	Order -	Crit. speed rpm
5.663	6.0	55.1
	12.0	27.5
	18.0	18.4
0.258	3.0	110.1
	9.0	36.7
	15.0	22.0
0.097	4.0	82.6
	8.0	41.3
	10.0	33.0
	14.0	23.6
	16.0	20.7
	5.0	66.1
0.046	7.0	47.2
	11.0	30.0
	13.0	25.4
	17.0	19.4

Natural mode 2
 Natural frequency 1405.931 cpm

No	Element	Rel. ampl. rad	Torque Nm
1	FLANGE	1.00000	0.45954E+07
2	CYLINDER NO. 1	0.99733	0.24588E+09
3	CYLINDER NO. 2	0.81786	0.44374E+09
4	CYLINDER NO. 3	0.49862	0.56437E+09
5	CYLINDER NO. 4	0.08056	0.58386E+09
6	CYLINDER NO. 5	-0.34252	0.50100E+09
7	CYLINDER NO. 6	-0.69044	0.33396E+09
8	CAMSHAFT DRIVE	-0.86808	0.24360E+09
9	TURNING WHEEL	-0.95698	-0.44448E+08
10	FLANGE	-0.39901	-0.49741E+08
11	PROPELLER+AW	0.03541	

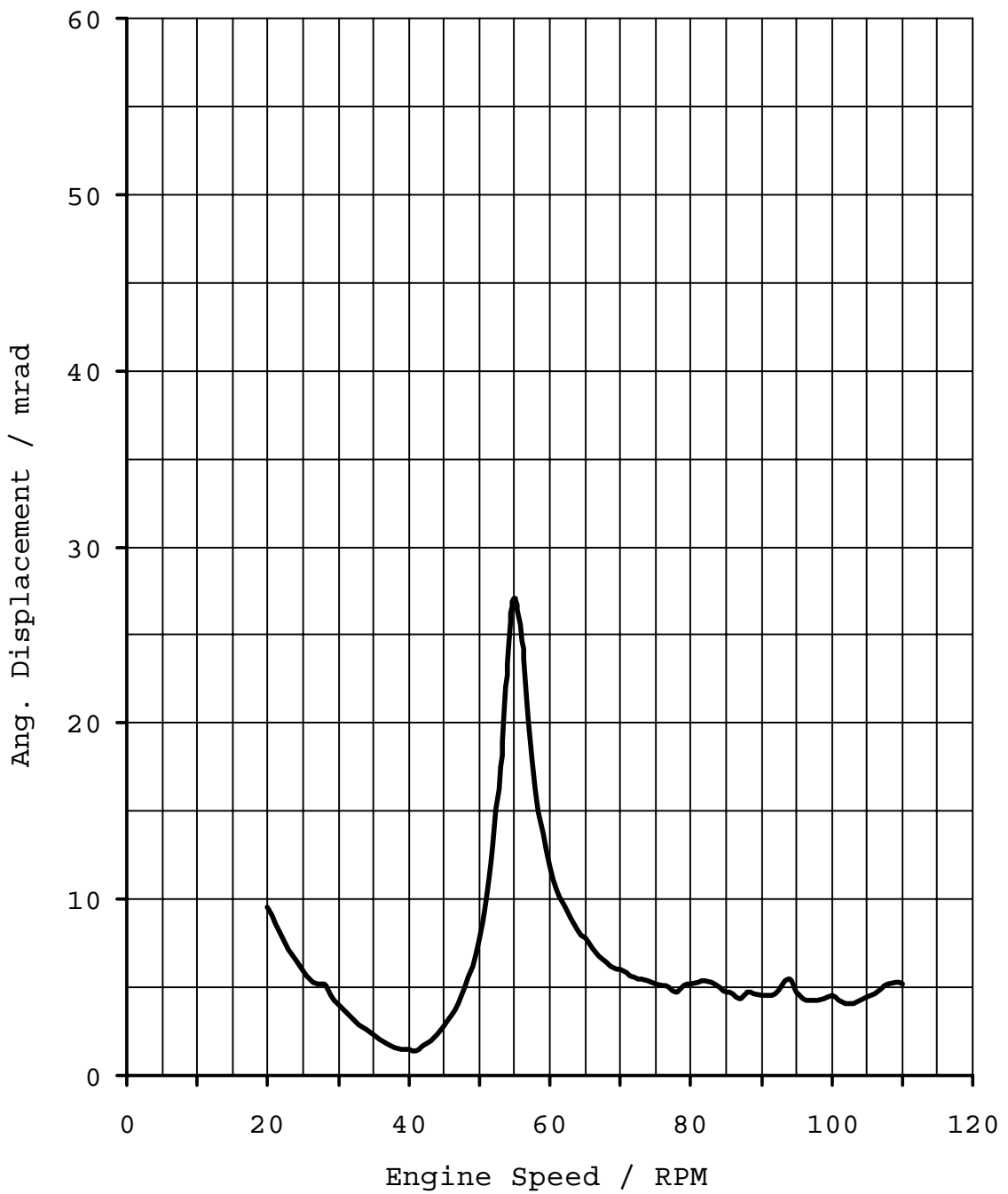
Critical Speeds

Vector sum rad	Order -	Crit. speed rpm
3.108	15.0	108.6
3.266	15.0	93.7
1.361	12.0	117.2
	18.0	78.1
1.100	14.0	100.4
	16.0	87.9
	20.0	70.3
0.259	11.0	127.8
	13.0	108.1
	17.0	82.7
	19.0	74.0

ANGULAR DISPLACEMENT - SPEED DIAGRAM

FLANGE
ELEMENT: 1

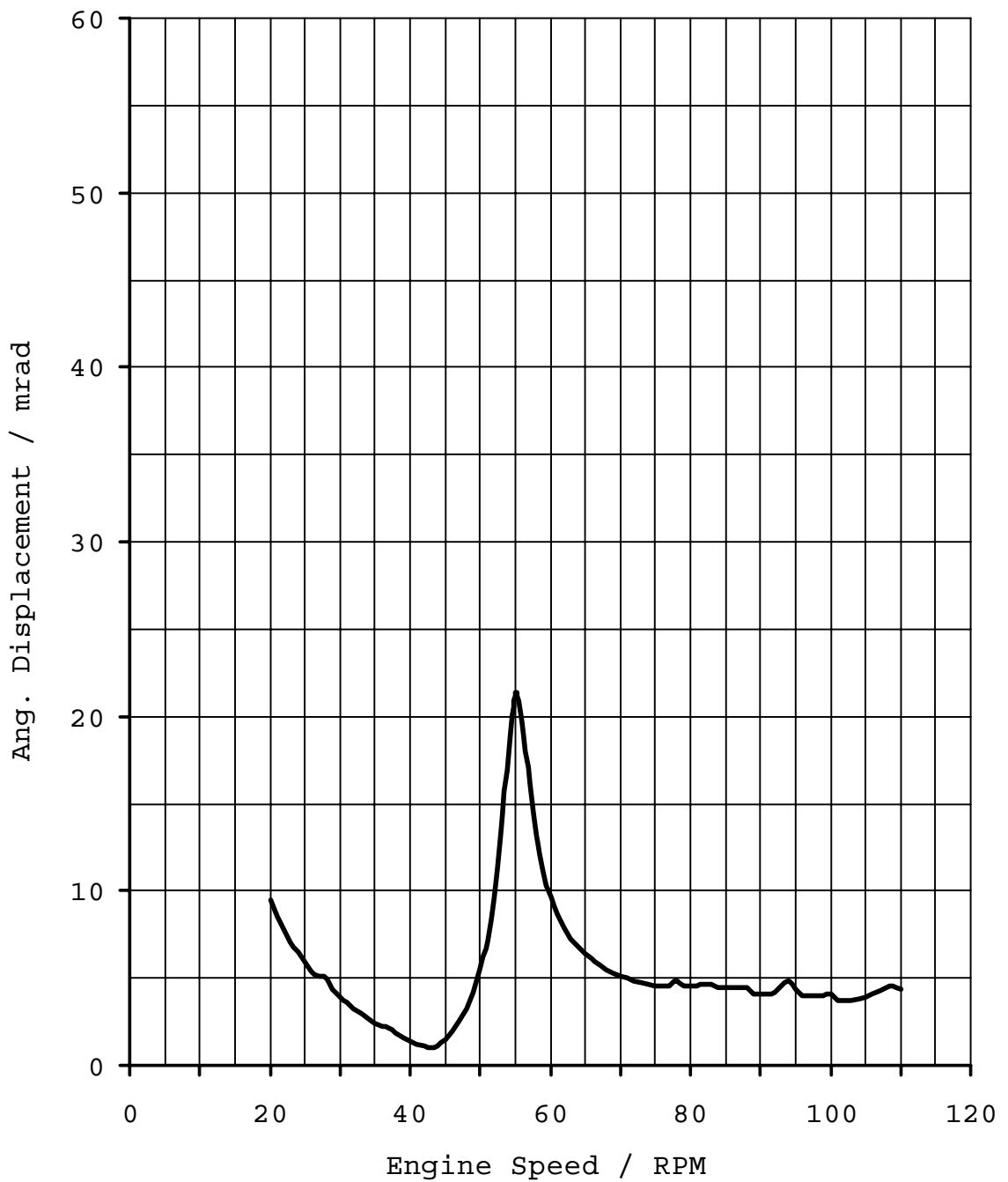
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ANGULAR DISPLACEMENT - SPEED DIAGRAM

TURNING WHEEL
ELEMENT: 9

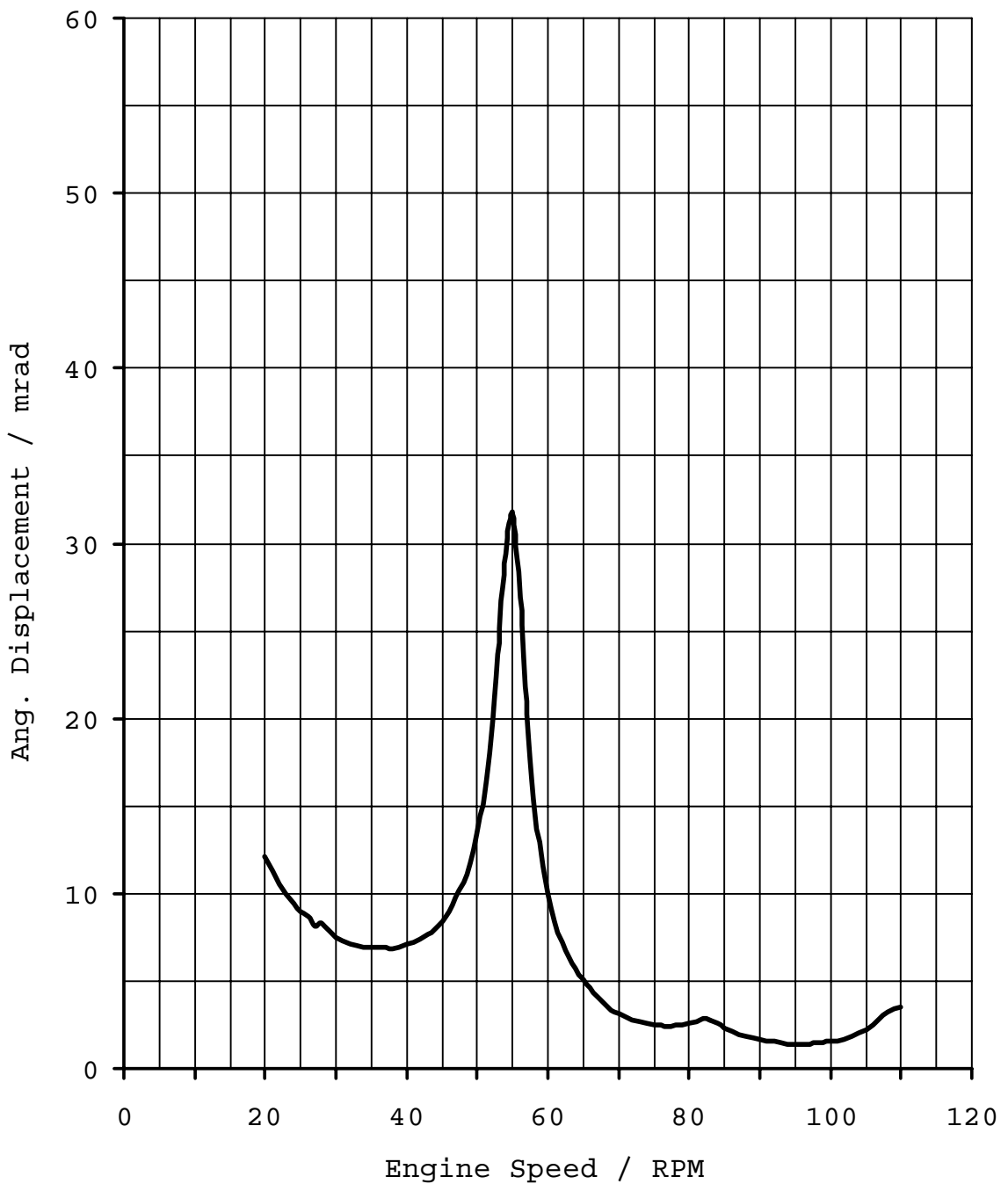
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ANGULAR DISPLACEMENT - SPEED DIAGRAM

PROPELLER
ELEMENT: 11

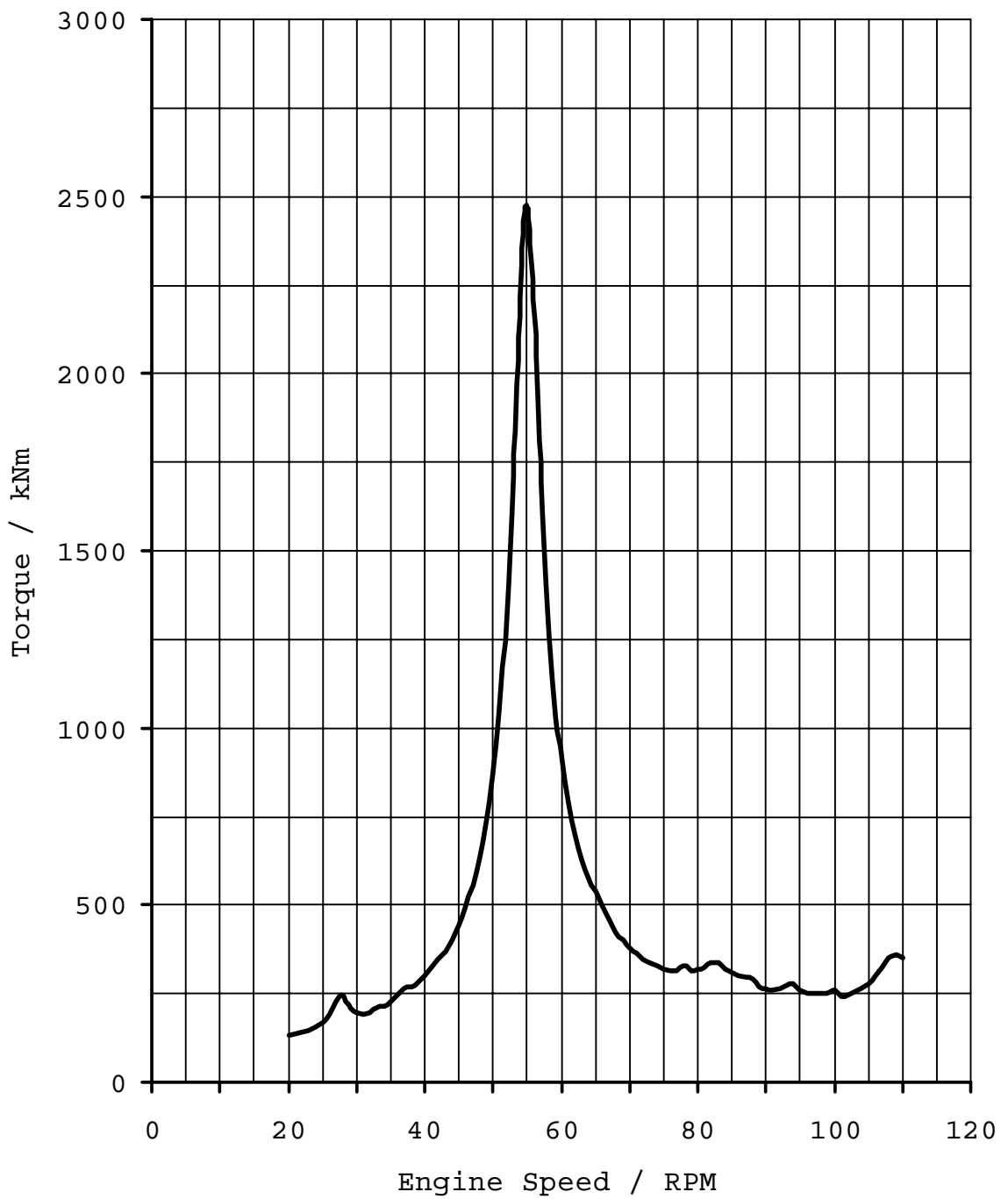
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TORQUE - SPEED DIAGRAM

INTERMEDIATE SHAFT
ELEMENT: 9-10

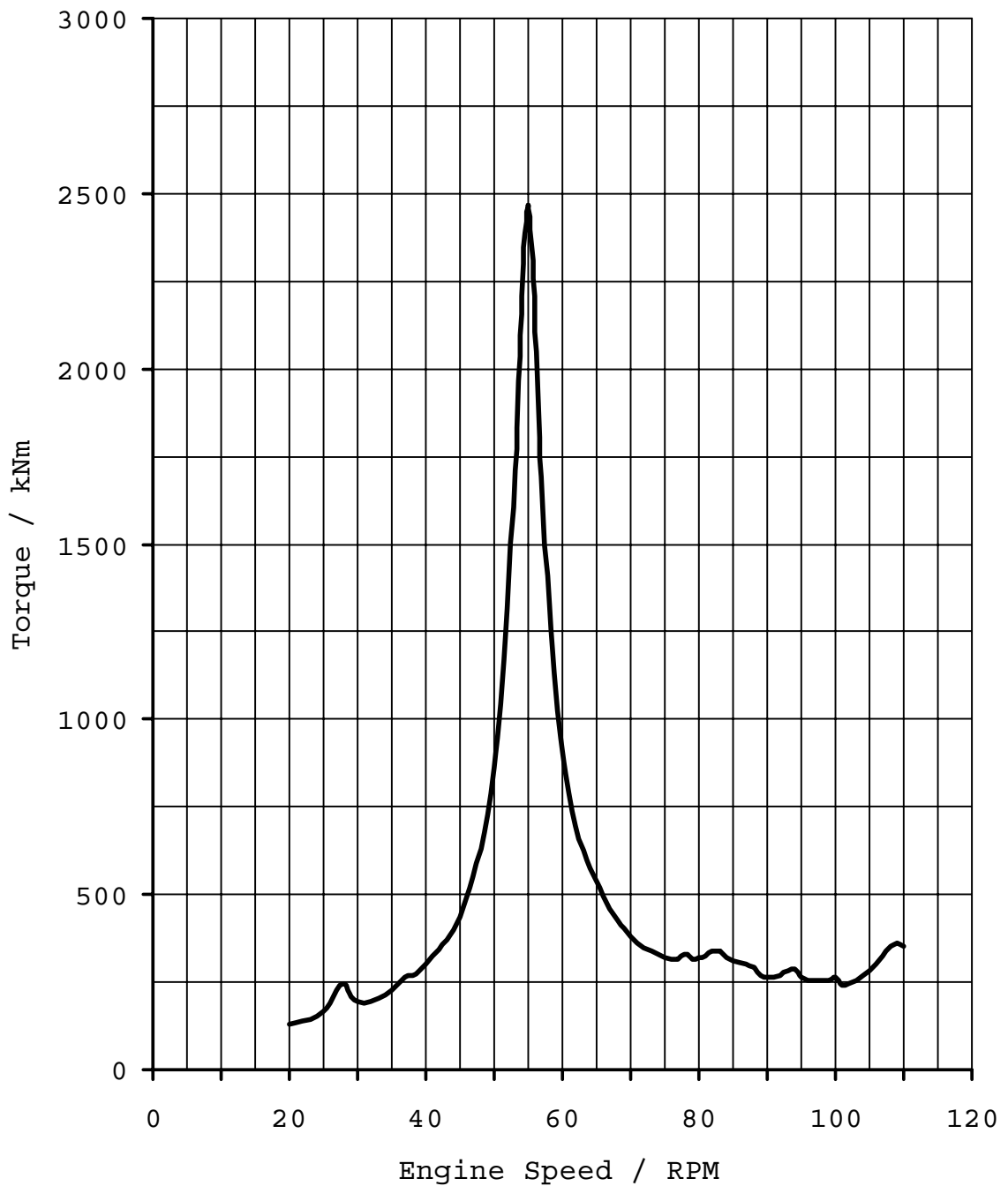
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TORQUE - SPEED DIAGRAM

PROPELLER SHAFT
ELEMENT: 10-11

OPERATION: NORMAL
LOAD: PROPELLER LAW

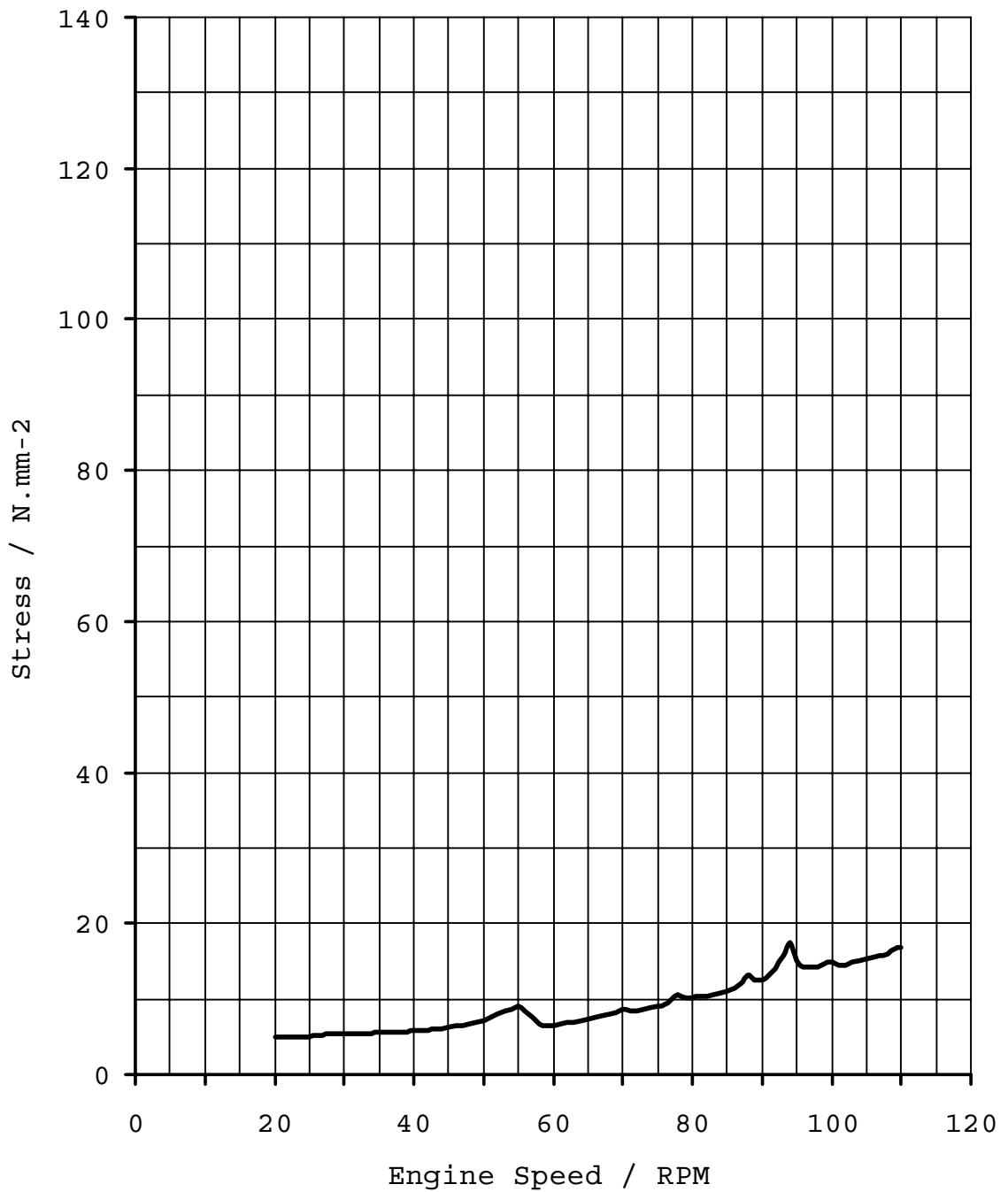


STRESS - SPEED DIAGRAM

CRANKSHAFT (CYLINDER No.1 - CYLINDER No.2)

ELEMENT: 2-3

OPERATION: NORMAL
LOAD: PROPELLER LAW

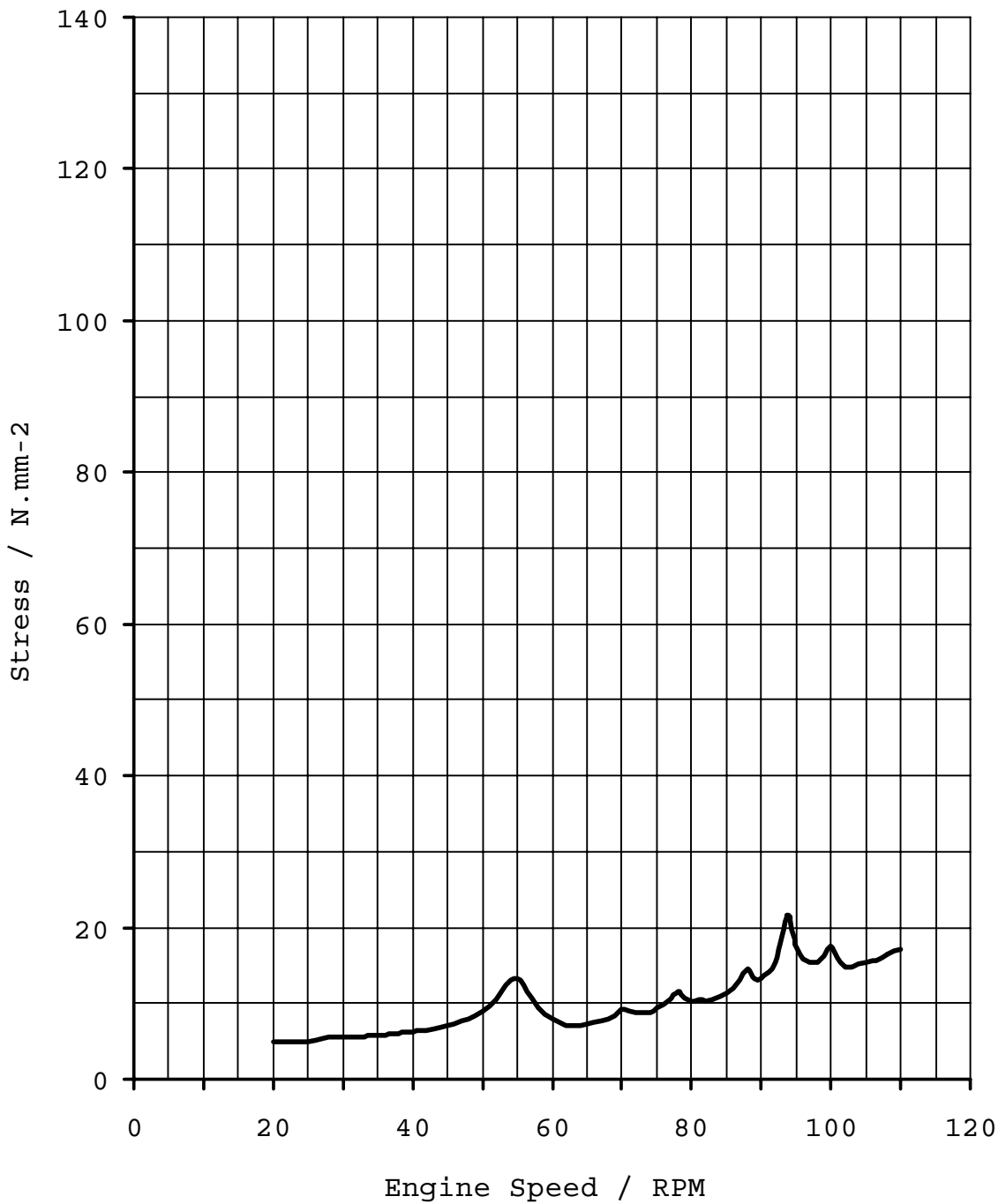


STRESS - SPEED DIAGRAM

CRANKSHAFT (CYLINDER No.2 - CYLINDER No.3)

ELEMENT: 3-4

OPERATION: NORMAL
LOAD: PROPELLER LAW

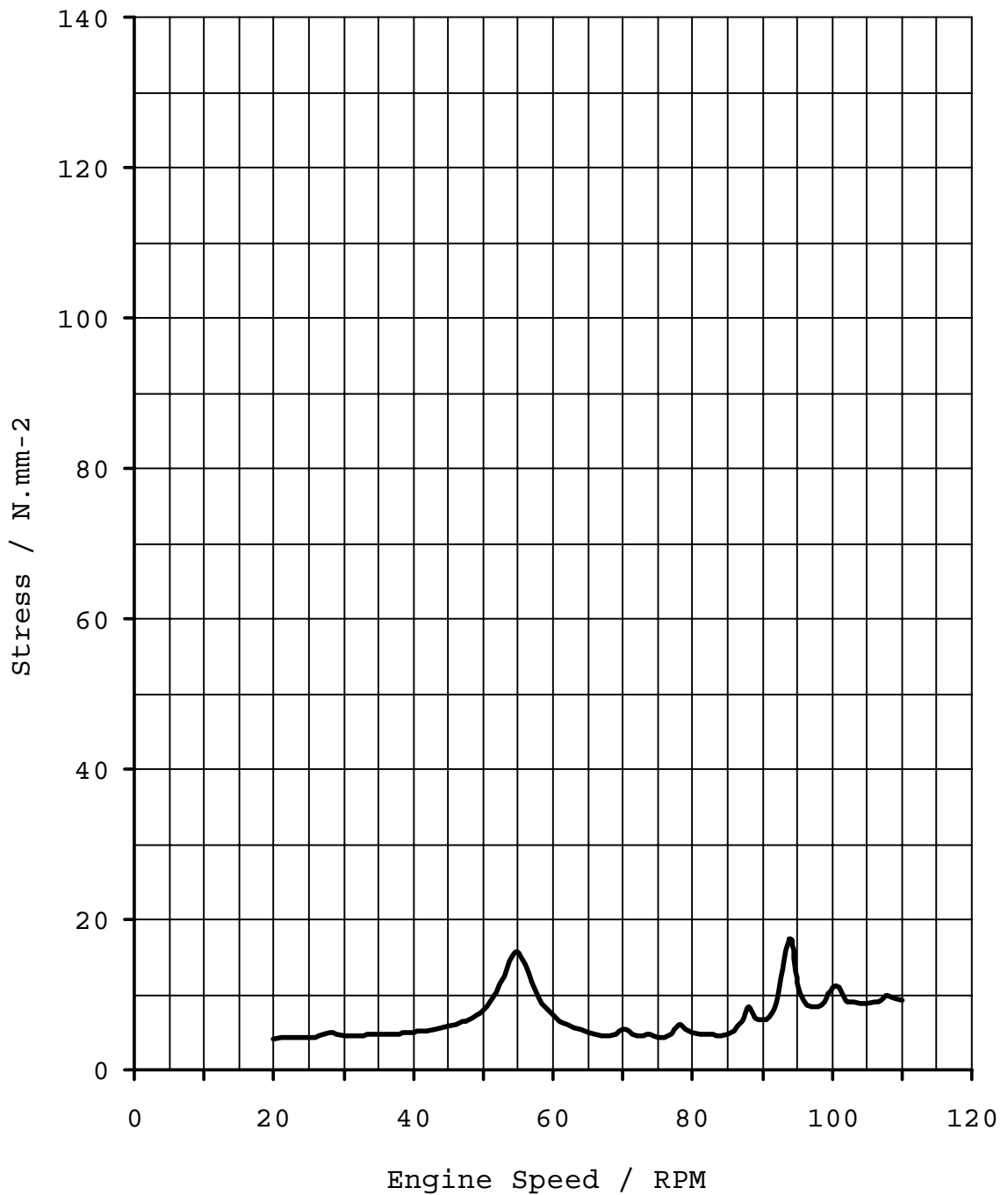


STRESS - SPEED DIAGRAM

CRANKSHAFT (CYLINDER No.3 - CYLINDER No.4)

ELEMENT: 4-5

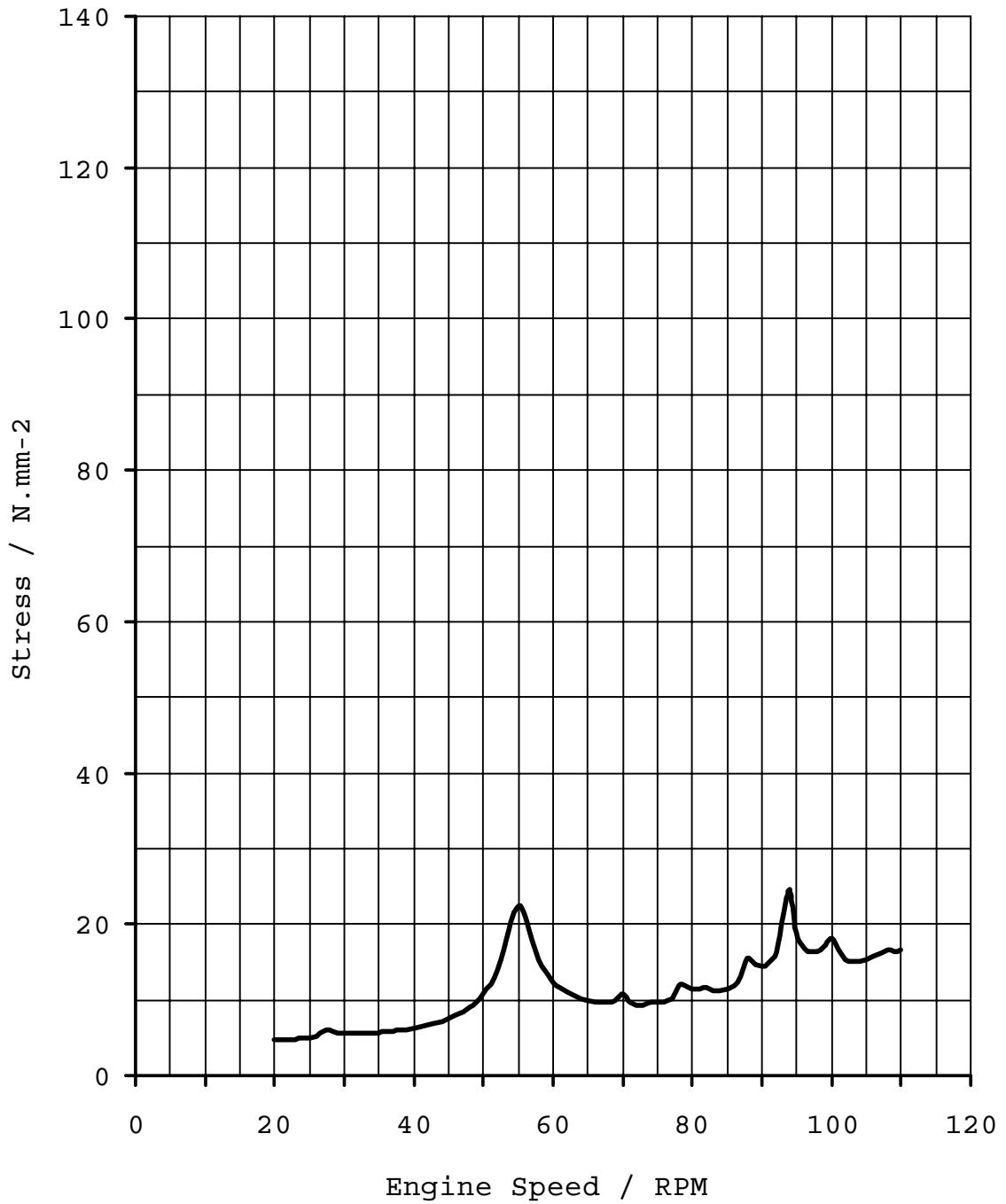
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LOAD: PROPELLER LAW



STRESS - SPEED DIAGRAM

CRANKSHAFT (CYLINDER No.4 - CYLINDER No.5)
ELEMENT: 5-6

OPERATION: NORMAL
LOAD: PROPELLER LAW

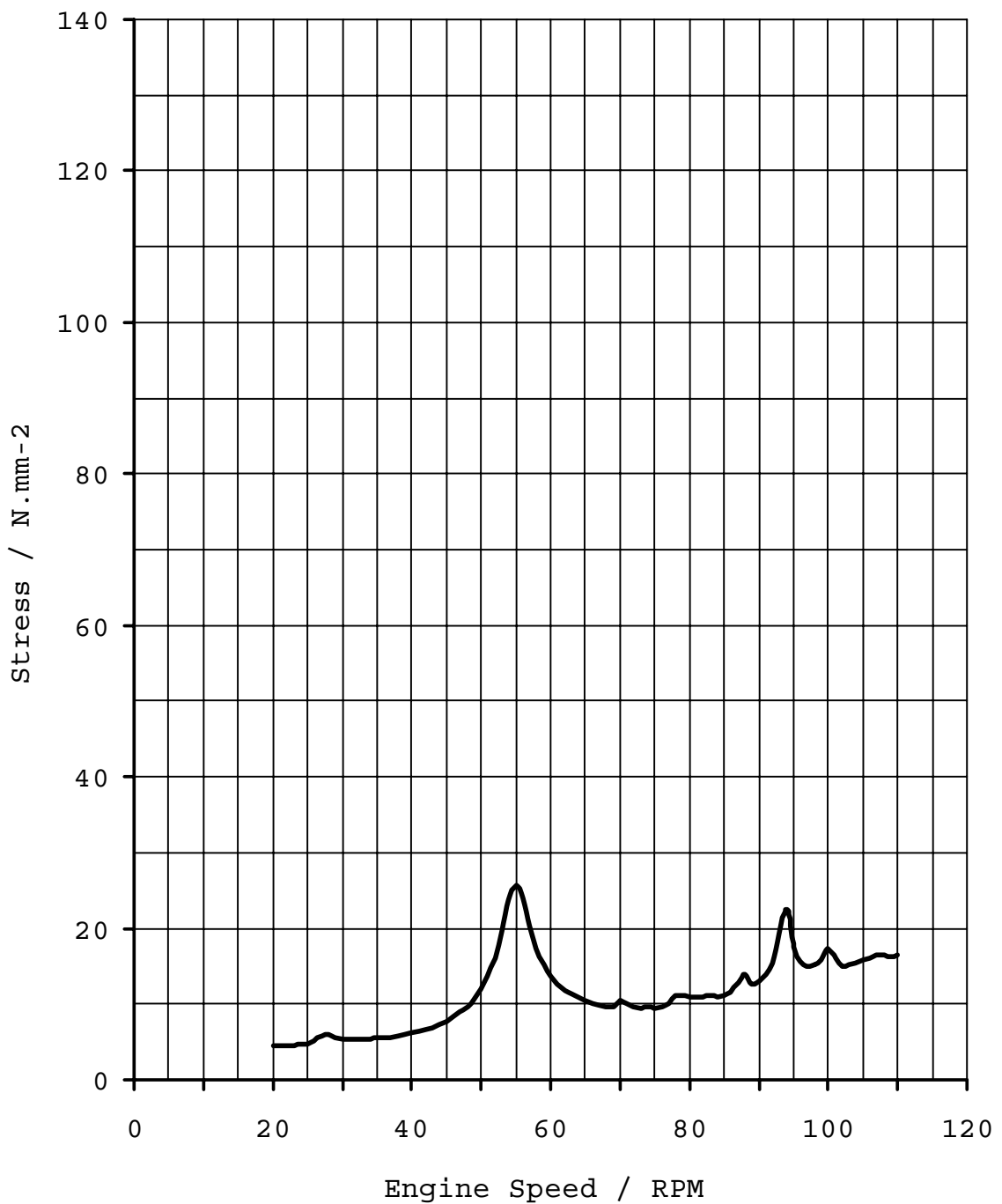


STRESS - SPEED DIAGRAM

CRANKSHAFT (CYLINDER No.5 - CYLINDER No.6)

ELEMENT: 6-7

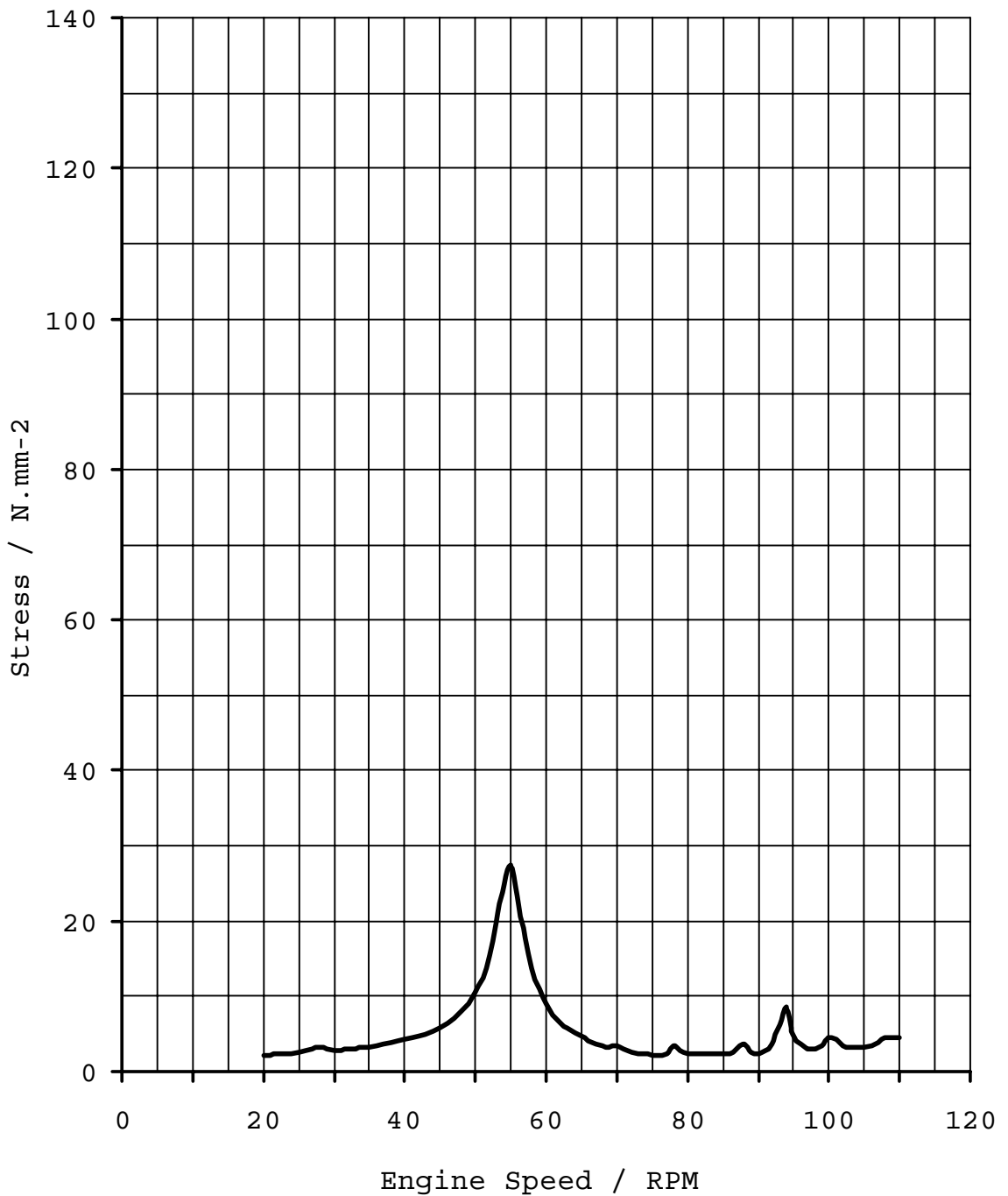
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LOAD: PROPELLER LAW



STRESS - SPEED DIAGRAM

CRANKSHAFT (CYLINDER No.6 - CAMSHAFT DRIVE)
ELEMENT: 7-8

OPERATION: NORMAL
LOAD: PROPELLER LAW

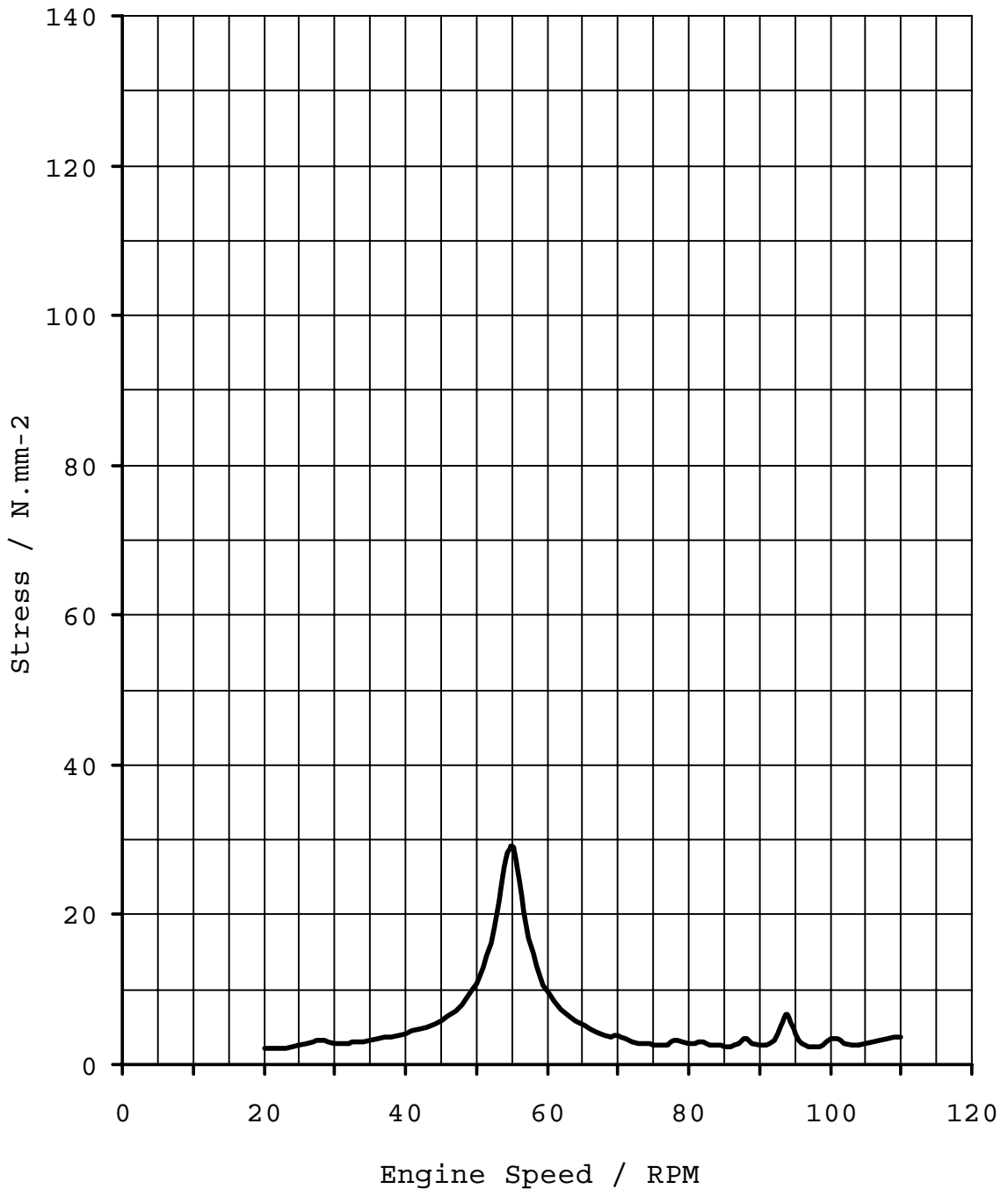


STRESS - SPEED DIAGRAM

CRANKSHAFT (CAMSHAFT DRIVE - TURNING WHEEL)

ELEMENT: 8-9

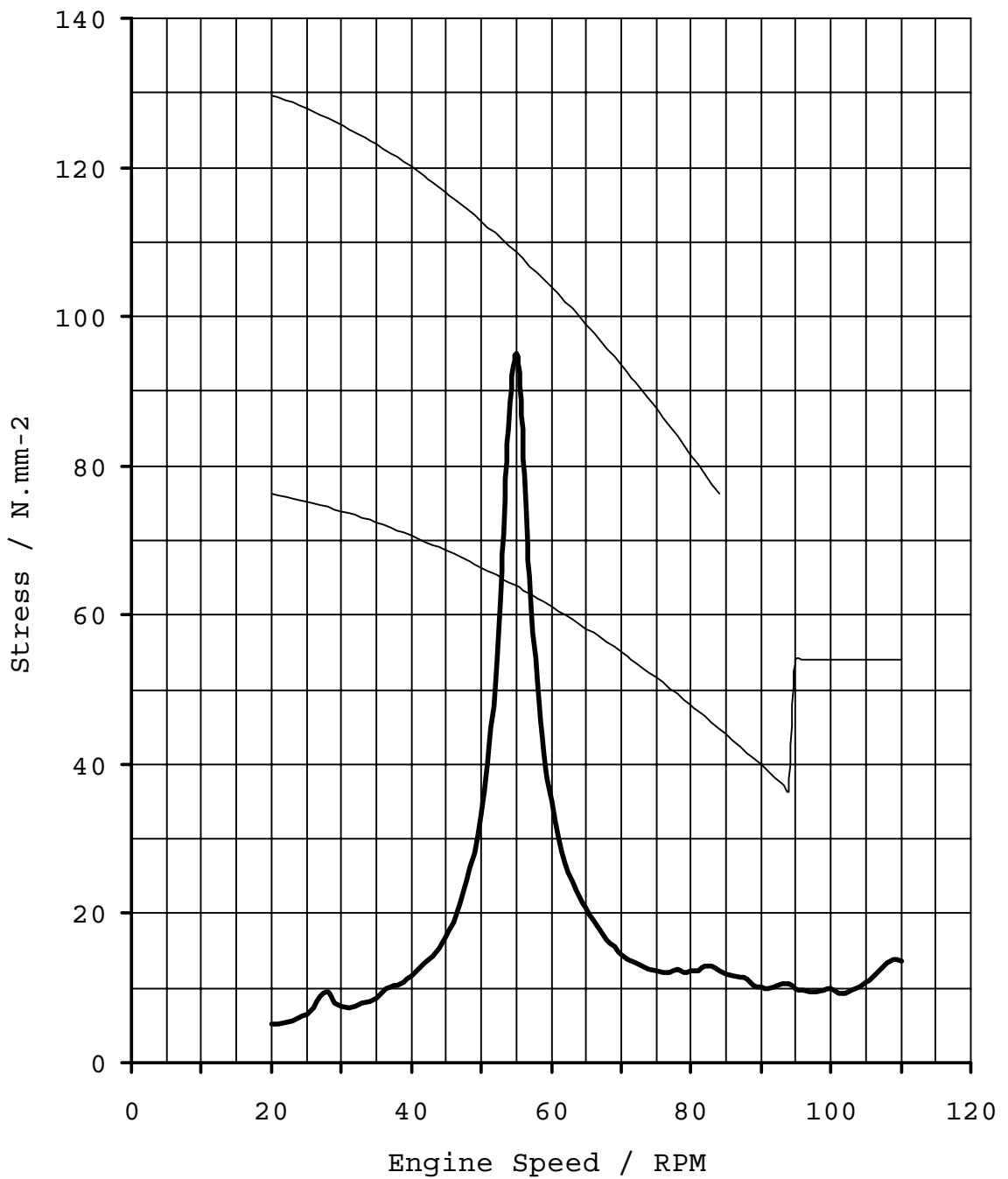
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STRESS - SPEED DIAGRAM

INTERMEDIATE SHAFT
ELEMENT: 9-10

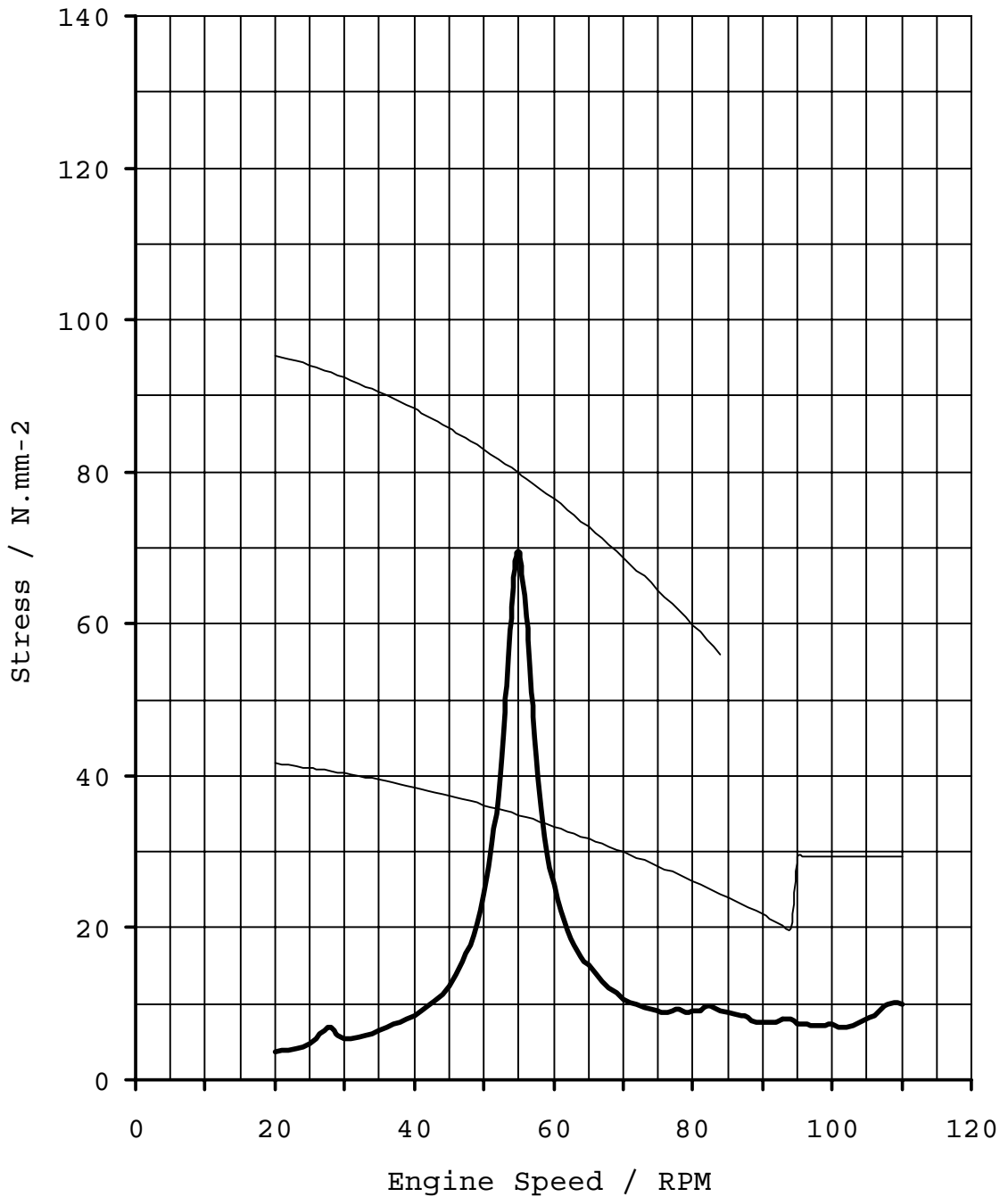
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STRESS - SPEED DIAGRAM

PROPELLER SHAFT
ELEMENT: 10-11

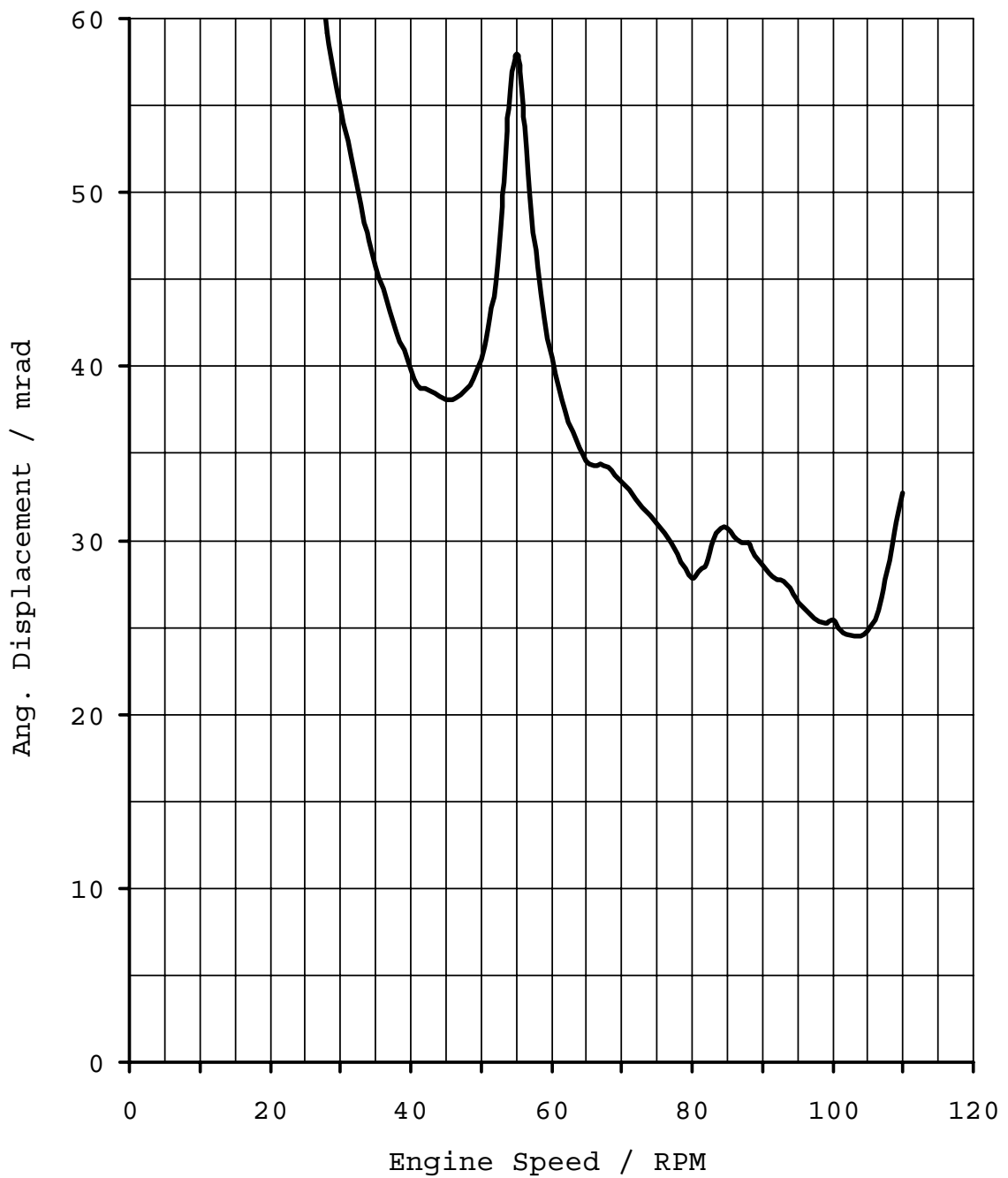
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ANGULAR DISPLACEMENT - SPEED DIAGRAM

FLANGE
ELEMENT: 1

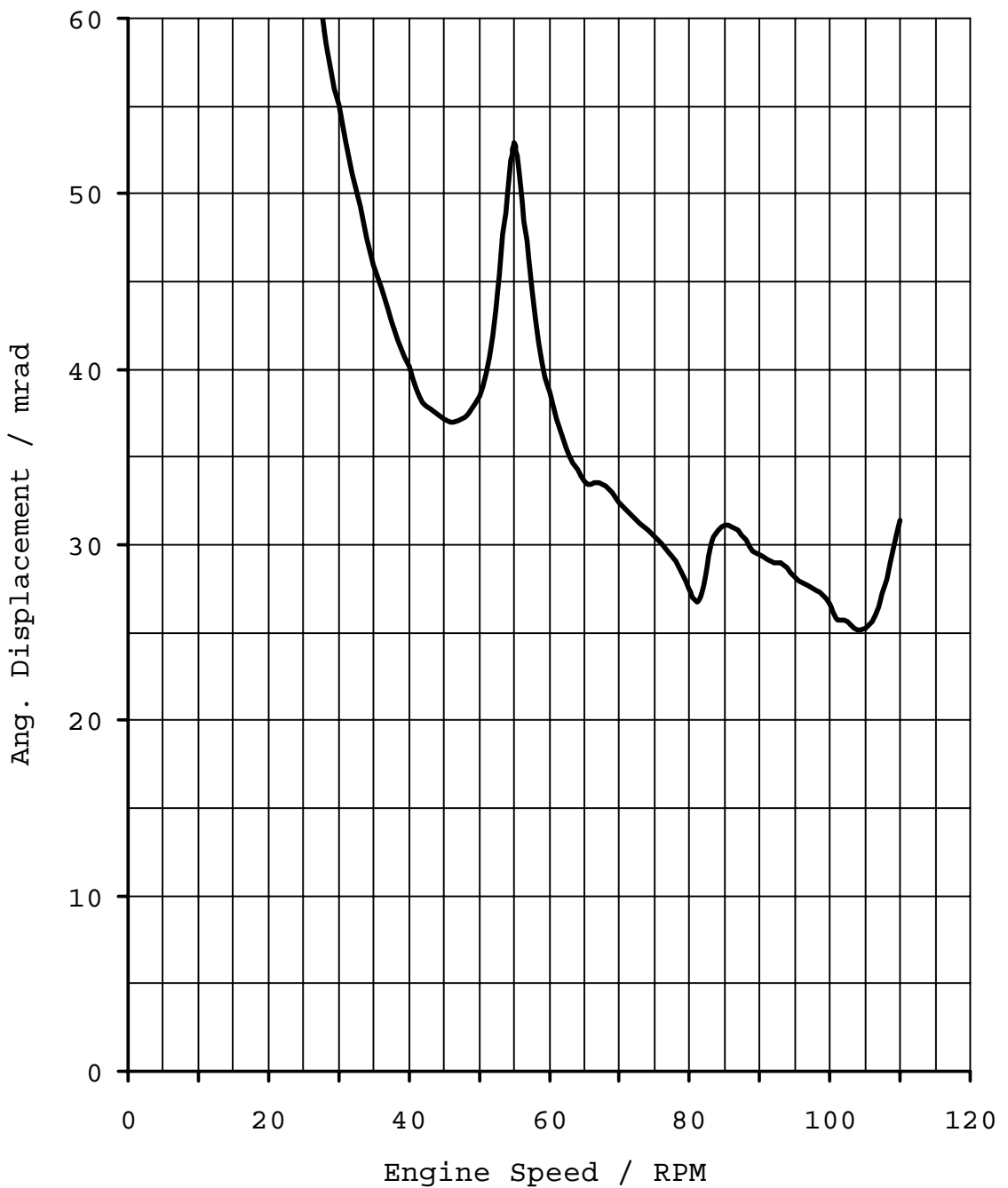
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ANGULAR DISPLACEMENT - SPEED DIAGRAM

TURNING WHEEL
ELEMENT: 9

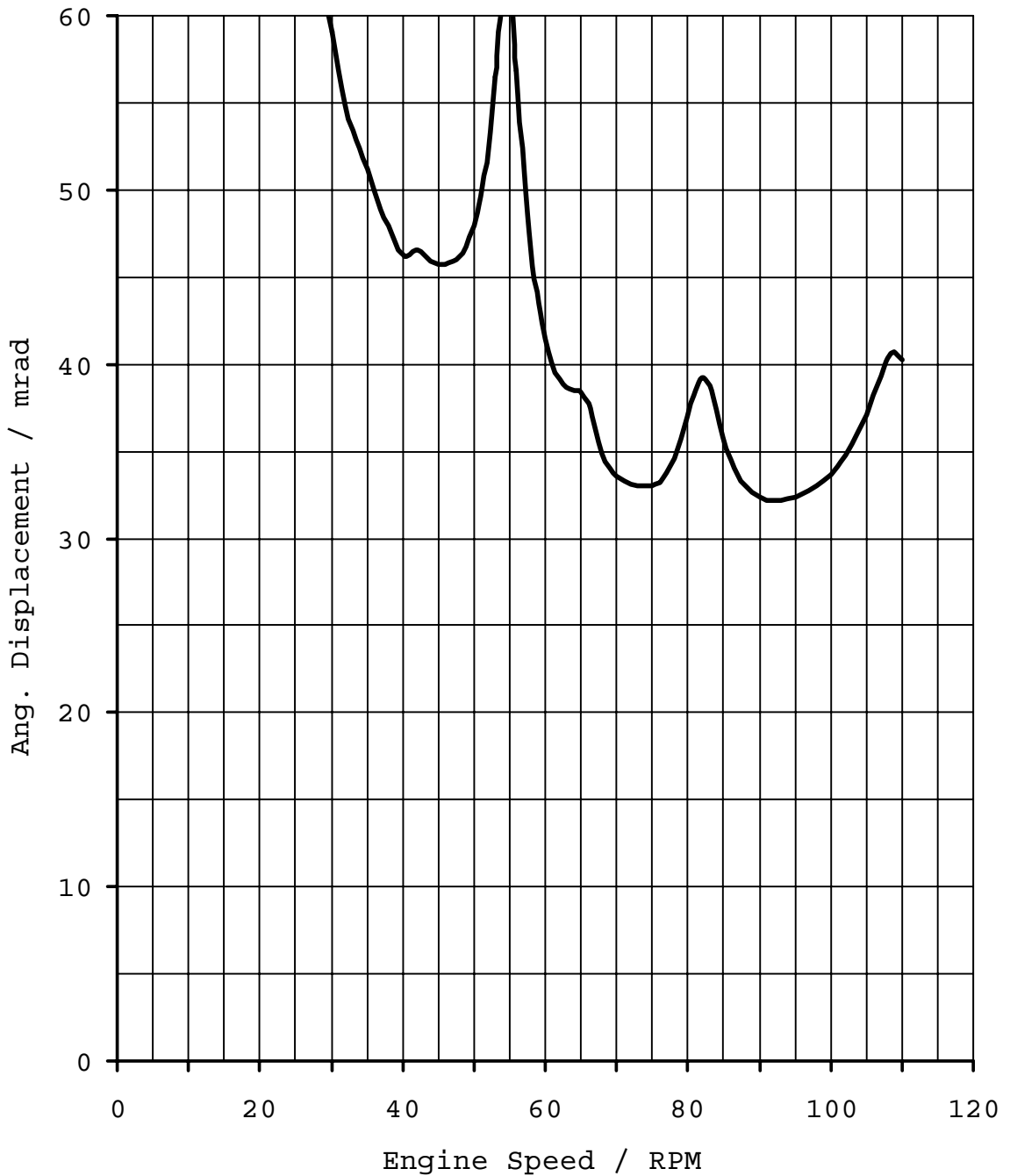
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ANGULAR DISPLACEMENT - SPEED DIAGRAM

PROPELLER
ELEMENT: 11

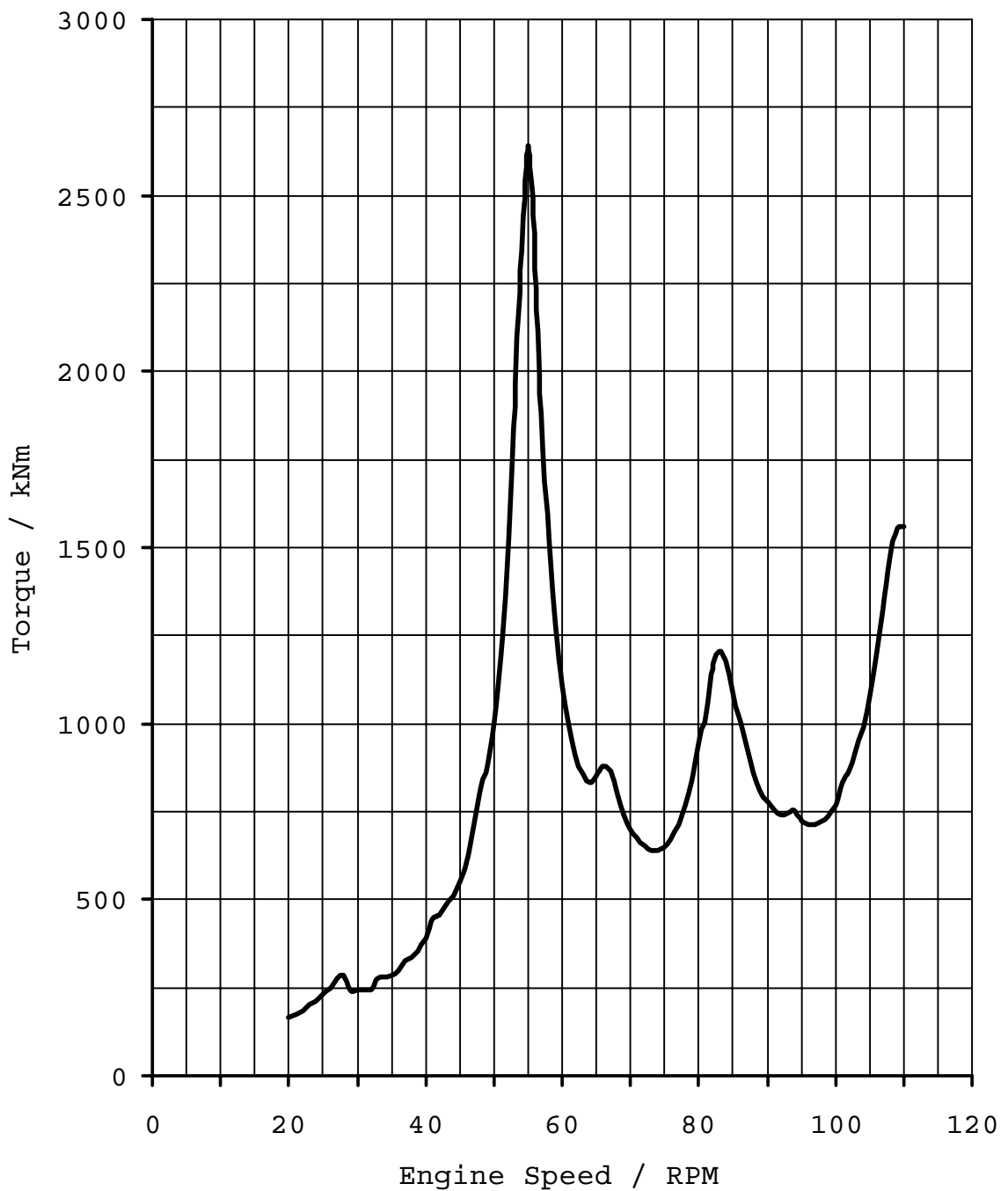
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TORQUE - SPEED DIAGRAM

INTERMEDIATE SHAFT
ELEMENT: 9-10

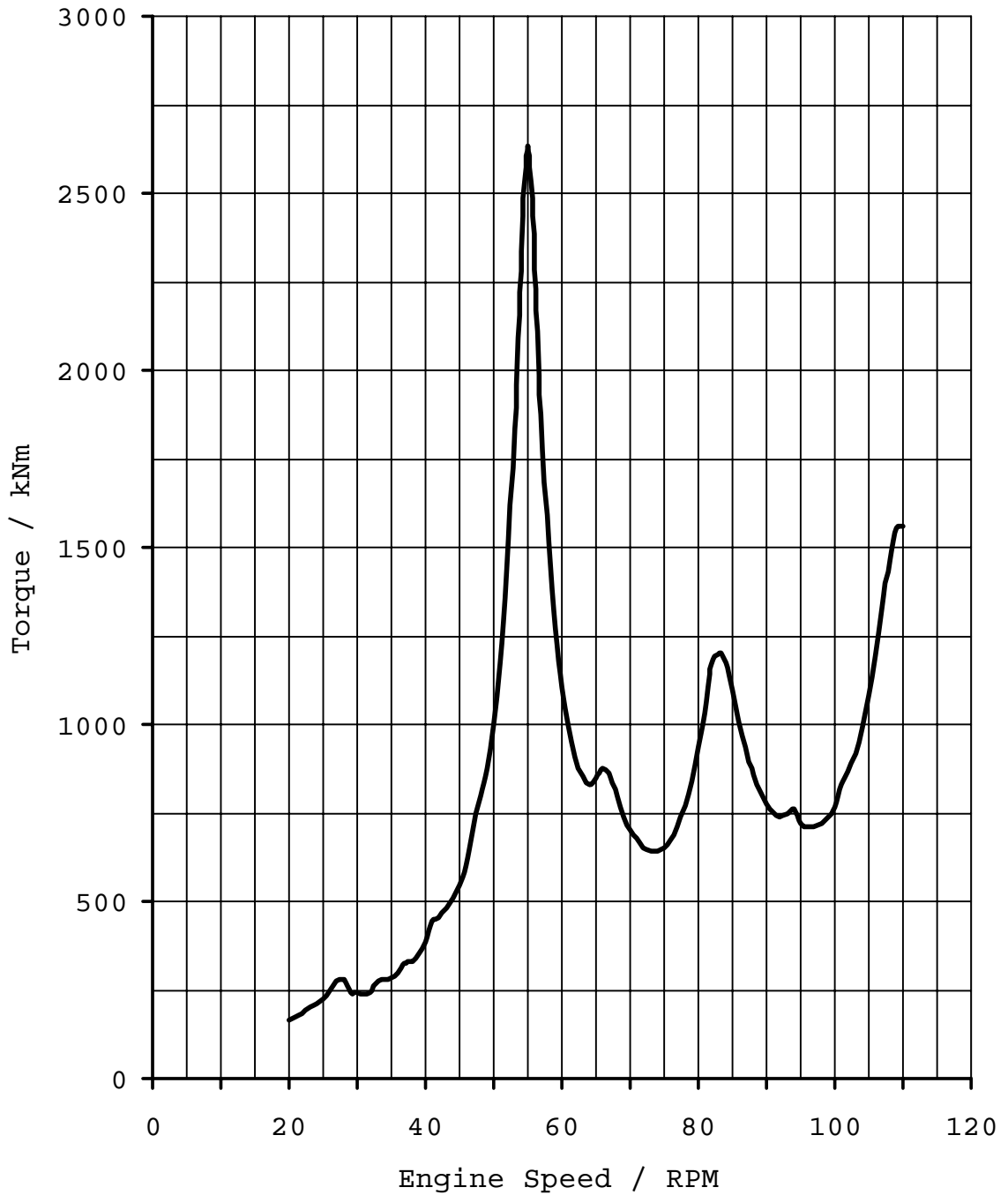
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TORQUE - SPEED DIAGRAM

PROPELLER SHAFT
ELEMENT: 10-11

OPERATION: CYLINDER No.3 MISFIRING
LOAD: PROPELLER LAW



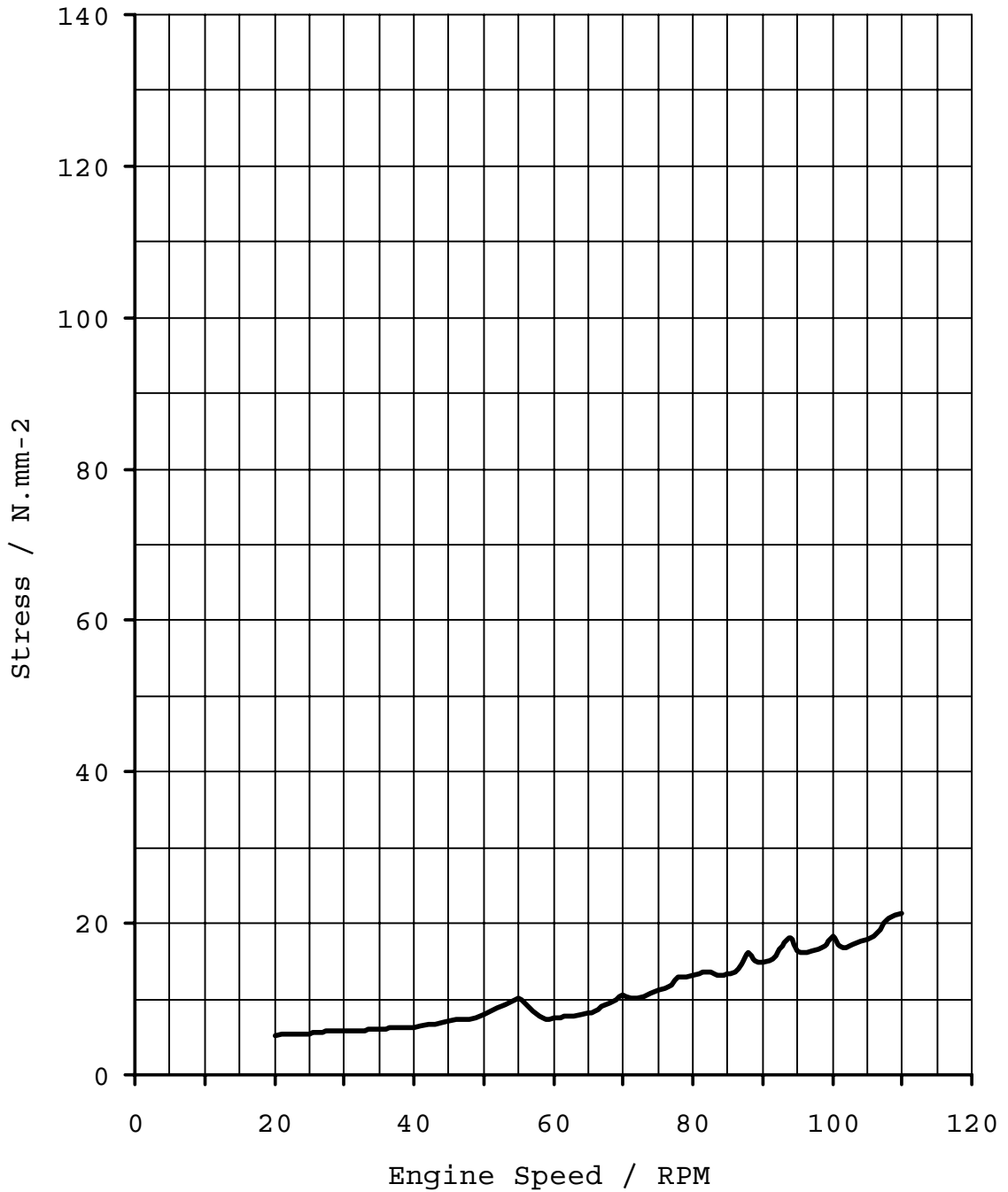
STRESS - SPEED DIAGRAM

CRANKSHAFT (CYLINDER No.1 - CYLINDER No.2)

ELEMENT: 2-3

OPERATION: CYLINDER No.3 MISFIRING

LOAD: PROPELLER LAW



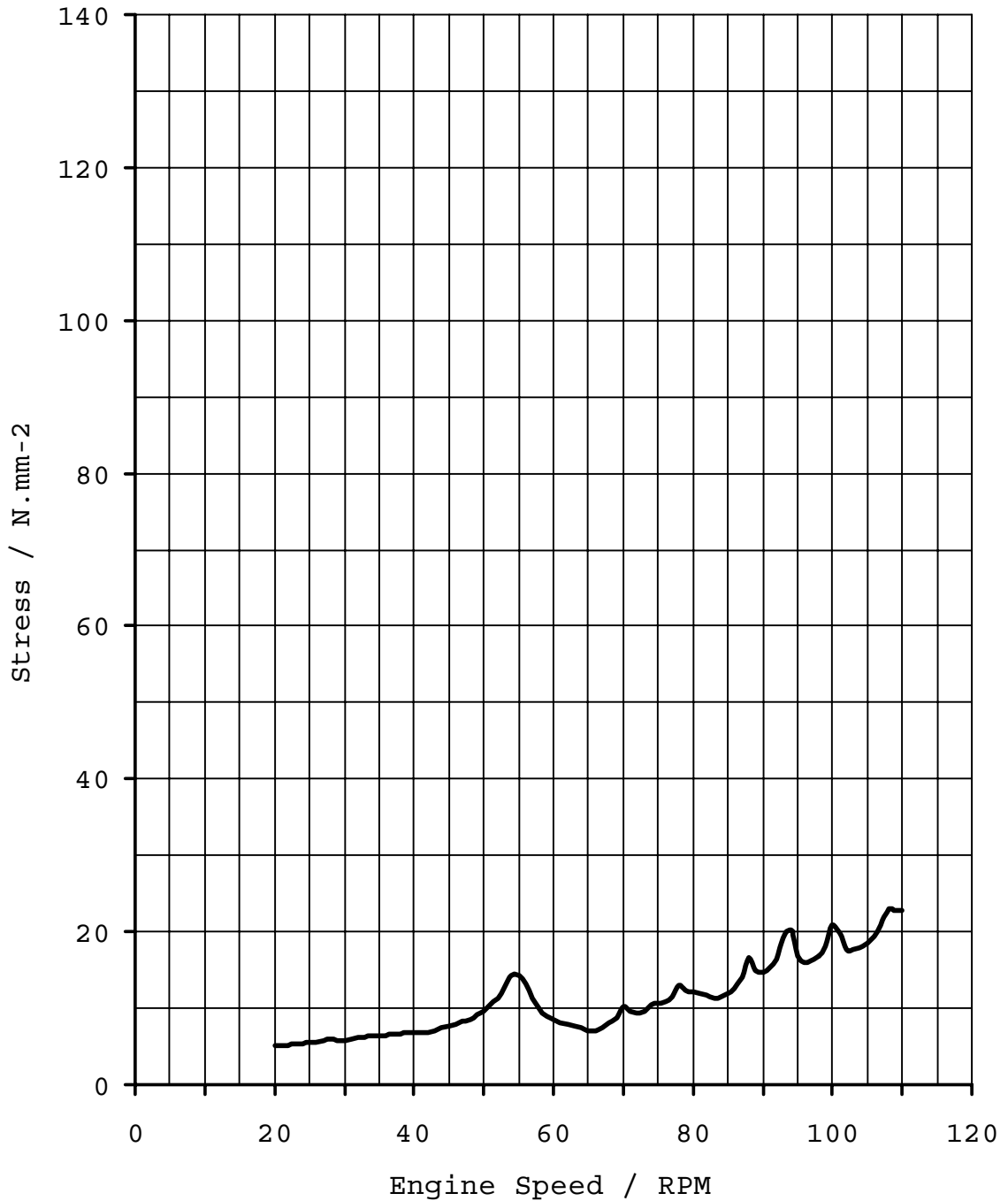
STRESS - SPEED DIAGRAM

CRANKSHAFT (CYLINDER No.2 - CYLINDER No.3)

ELEMENT: 3-4

OPERATION: CYLINDER No.3 MISFIRING

LOAD: PROPELLER LAW



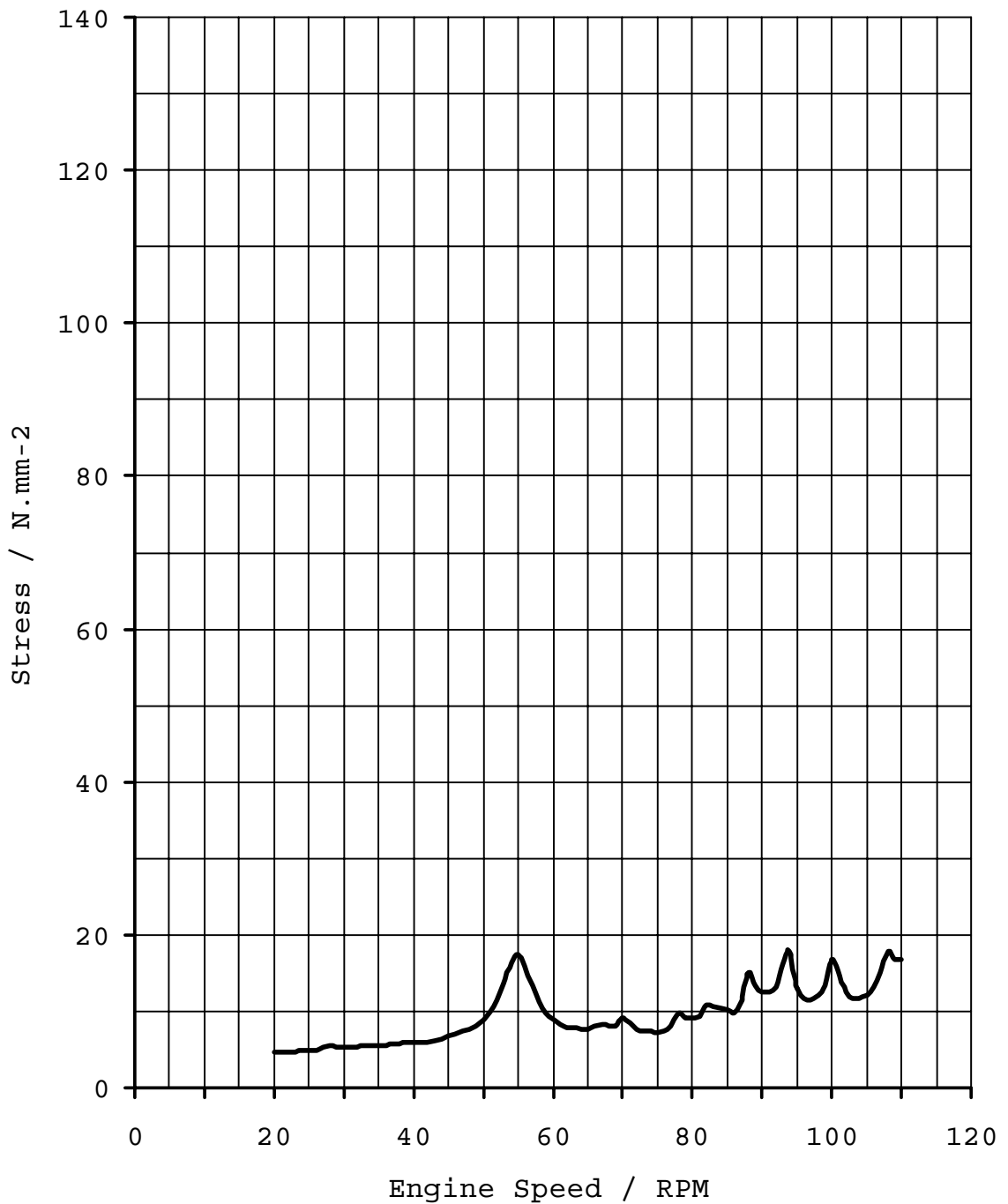
STRESS - SPEED DIAGRAM

CRANKSHAFT (CYLINDER No.3 - CYLINDER No.4)

ELEMENT: 4-5

OPERATION: CYLINDER No.3 MISFIRING

LOAD: PROPELLER LAW



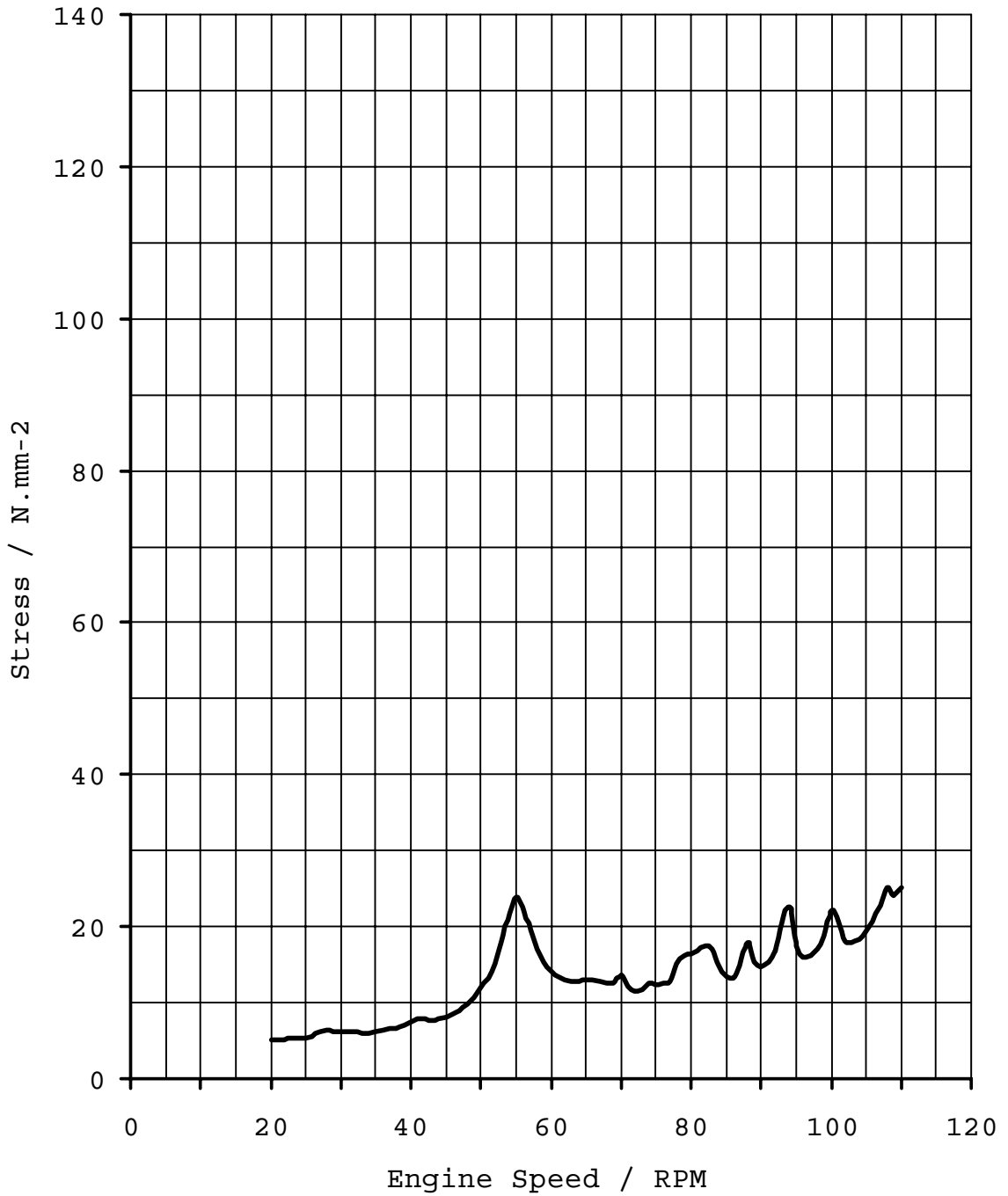
STRESS - SPEED DIAGRAM

CRANKSHAFT (CYLINDER No.4 - CYLINDER No.5)

ELEMENT: 5-6

OPERATION: CYLINDER No.3 MISFIRING

LOAD: PROPELLER LAW



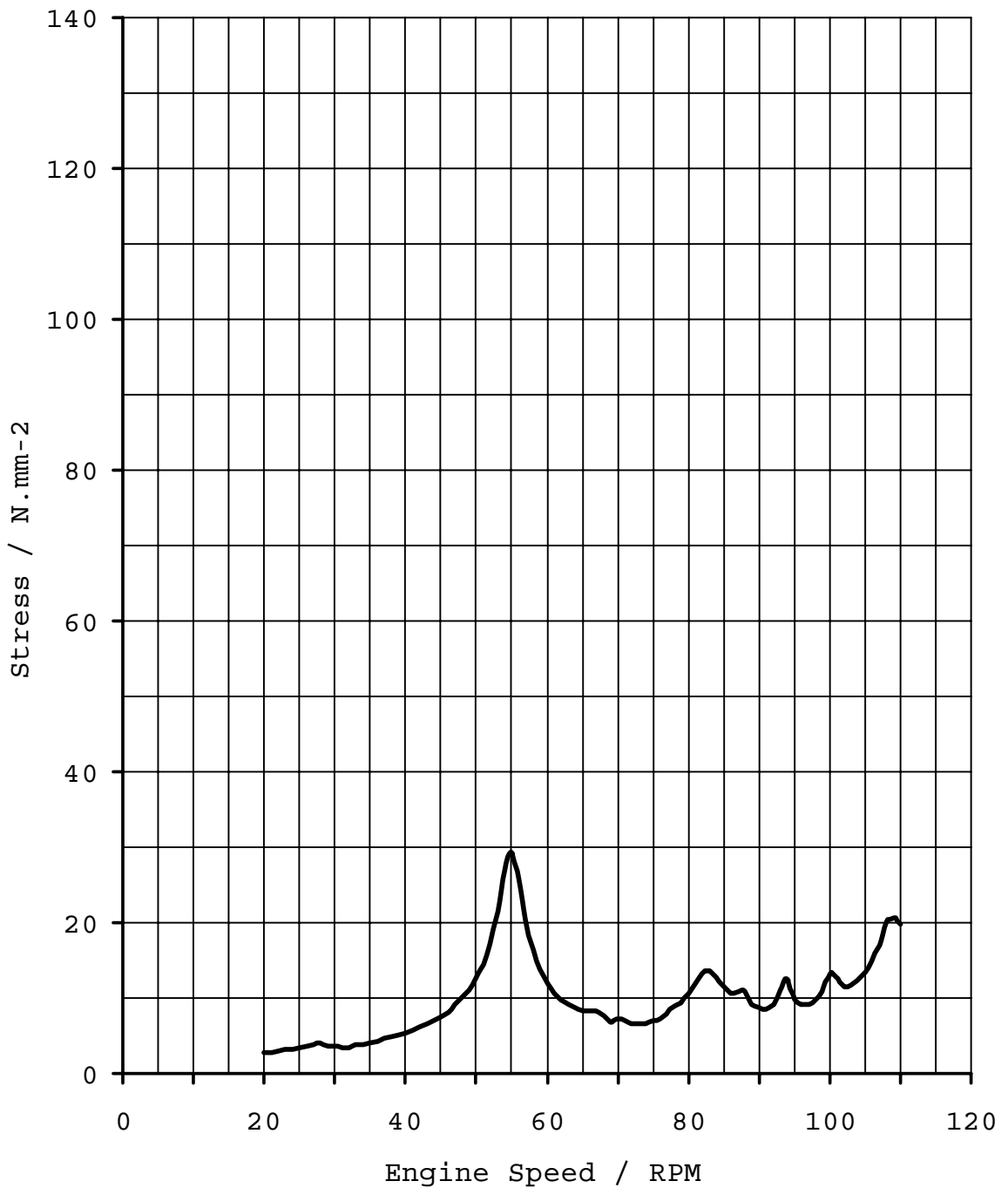
STRESS - SPEED DIAGRAM

CRANKSHAFT (CYLINDER No.5 - CYLINDER No.6)

ELEMENT: 6-7

OPERATION: CYLINDER No.3 MISFIRING

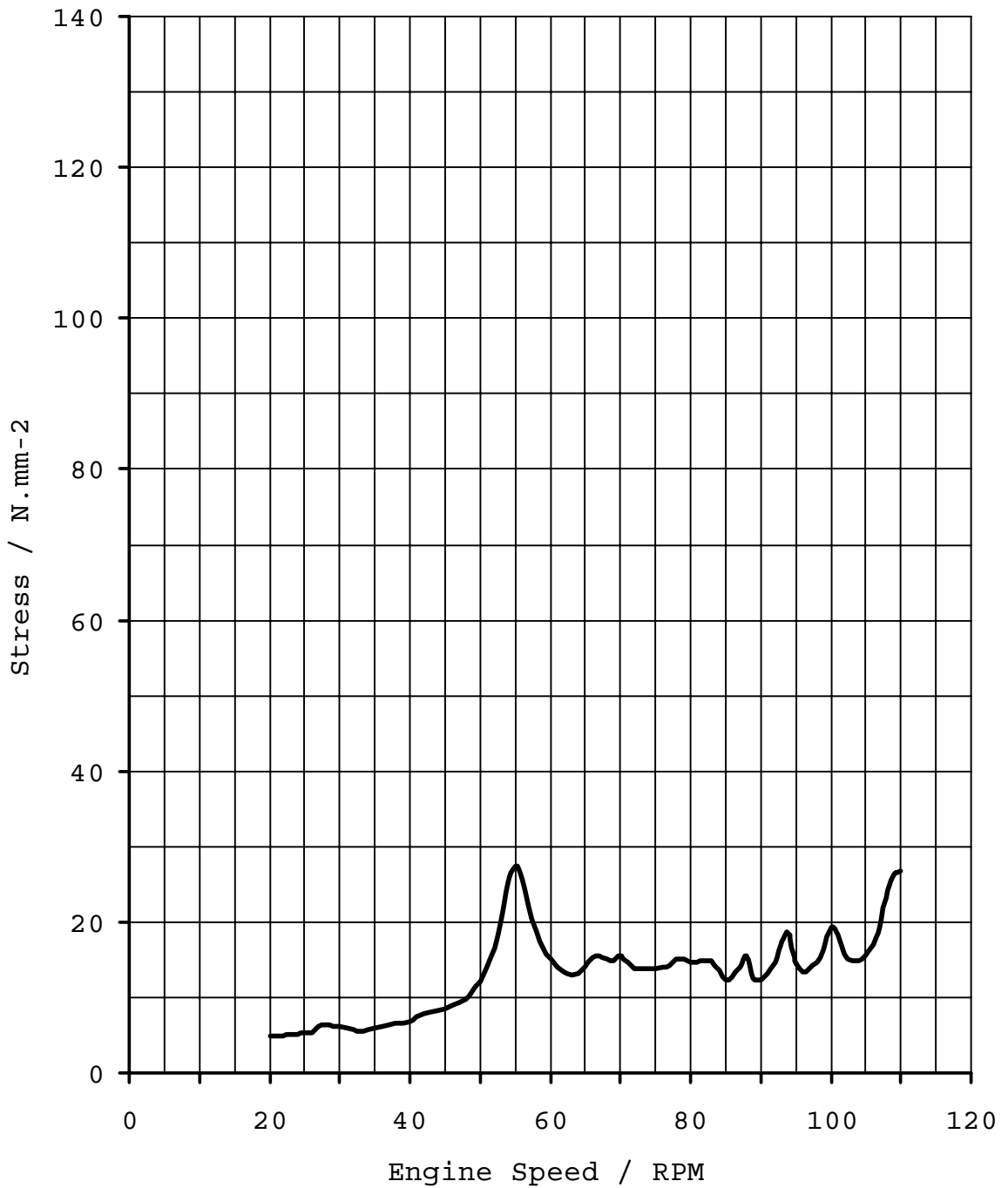
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STRESS - SPEED DIAGRAM

CRANKSHAFT (CYLINDER No.6 - CAMSHAFT DRIVE)
ELEMENT: 7-8

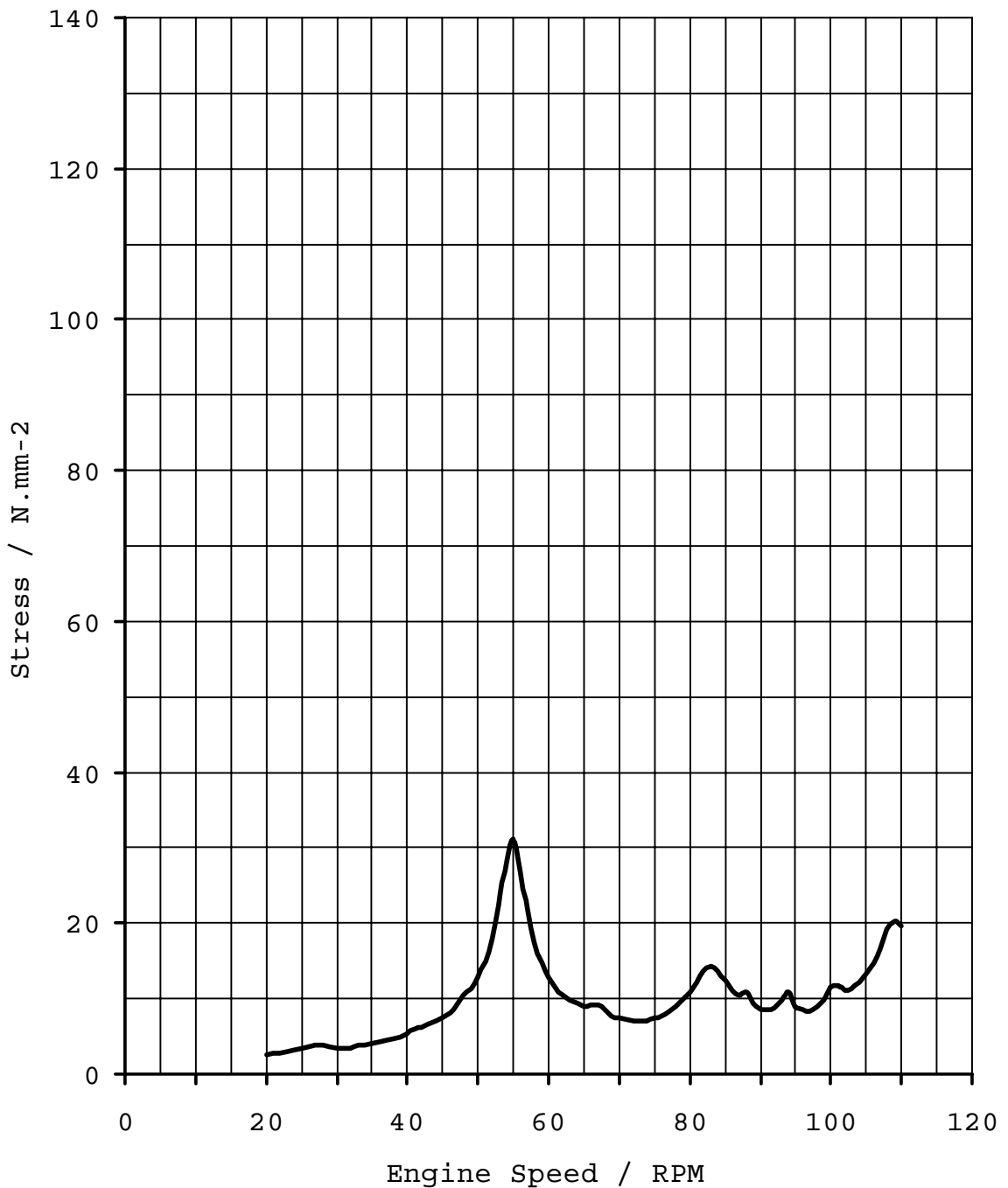
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STRESS - SPEED DIAGRAM

CRANKSHAFT (CAMSHAFT DRIVE - TURNING WHEEL)
ELEMENT: 8-9

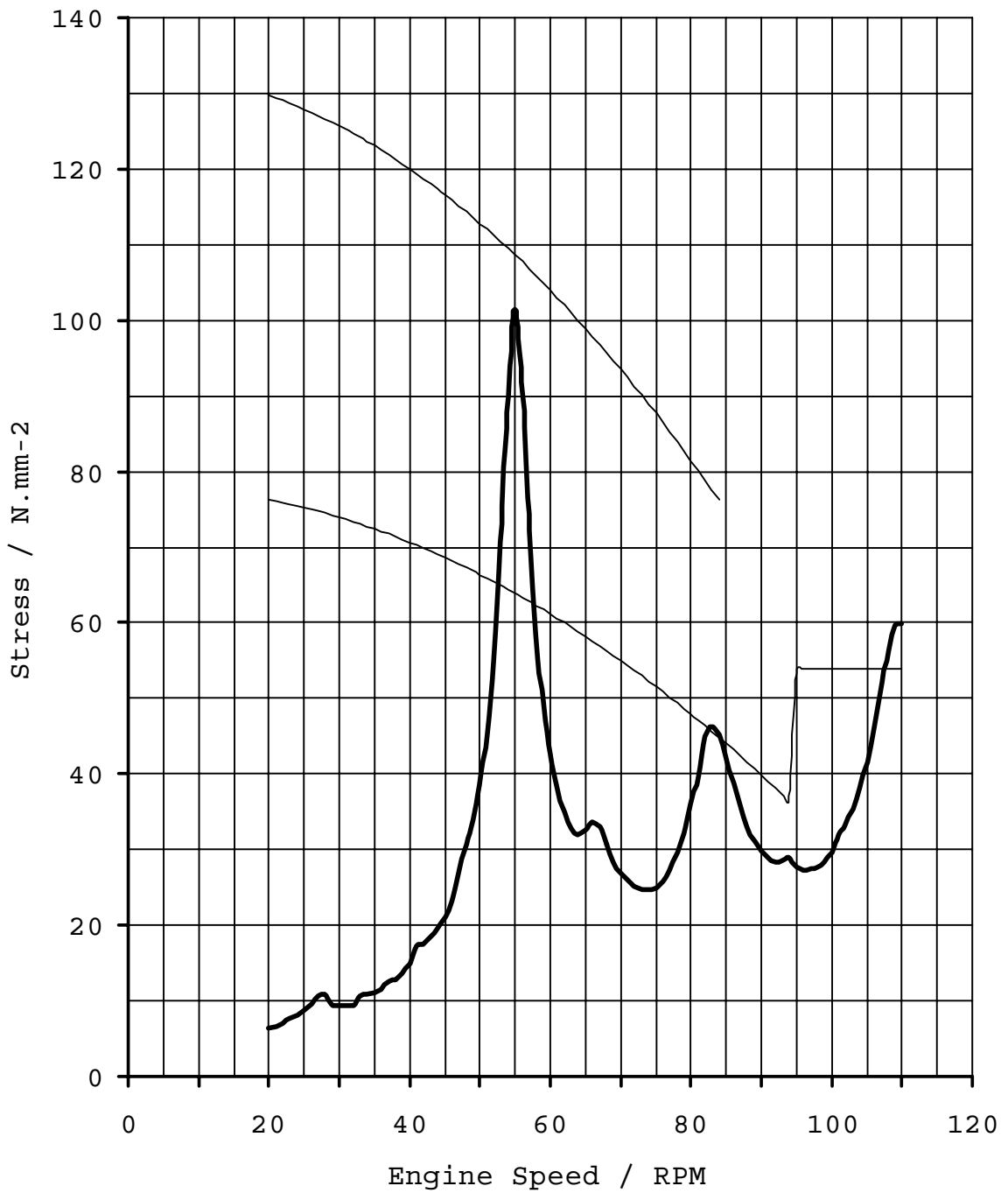
OPERATION: CYLINDER No.3 MISFIRING
LOAD: PROPELLER LAW



STRESS - SPEED DIAGRAM

INTERMEDIATE SHAFT
ELEMENT: 9-10

OPERATION: CYLINDER No.3 MISFIRING
LOAD: PROPELLER LAW



STRESS - SPEED DIAGRAM

PROPELLER SHAFT
ELEMENT: 10-11

OPERATION: CYLINDER No.3 MISFIRING
LOAD: PROPELLER LAW

