Processing Map for pure Mg and AZ31 alloy

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Processing Map

- The processing map is the superimposition of power dissipation and flow instability maps.
- It is constructed based on the dynamic materials model, a continuum model that considers the tool as a source of power and the material as a dissipator of power.
- These processing maps have been widely used for optimizing the processing parameters for hot working and the microstructures after deformation in many metals.

Procedure

For the Processing maps

- We have the flow stress values for particular strain rate values and temperatures.
- From the flow stress values and strain rate values we can find the strain rate sensitivity values m, which is simply the slope of the plot between log(flow stress) and log(strain rate).
- Once we find m, we can find efficiency of power dissipation which is given by

$$\eta = \frac{2m}{2m + 1}$$

- Similarly we also find the instability regions using the following inequation

$$\xi(\dot{\varepsilon}) = \frac{\partial \lg\left(\frac{m}{m+1}\right)}{\partial \lg \dot{\varepsilon}} + m \leq 0$$

- Now we can plot contour regions according to the data

Processing Map for As-cast Mg

Material: Magnesium

Composition: Fe-0.059, Ni-0.026, Pb-0.006, Cu-0.003 ,Mg-99.89 (min.)

Prior History: As-cast condition; Average grain diameter-1.5 mm at 475^{o}C

Introduction: Magnesium is a light metal (density-1.738 g/cc) and has a hexagonal closed packed (hcp) structure with a c/a ratio of 1.623 which is close to the ideal close packing value (1.633).

Since these alloys has hcp structure, these may be hot rolled to develop specific crystallographic textures that would improve the specific stiffness in certain directions.

Processing map

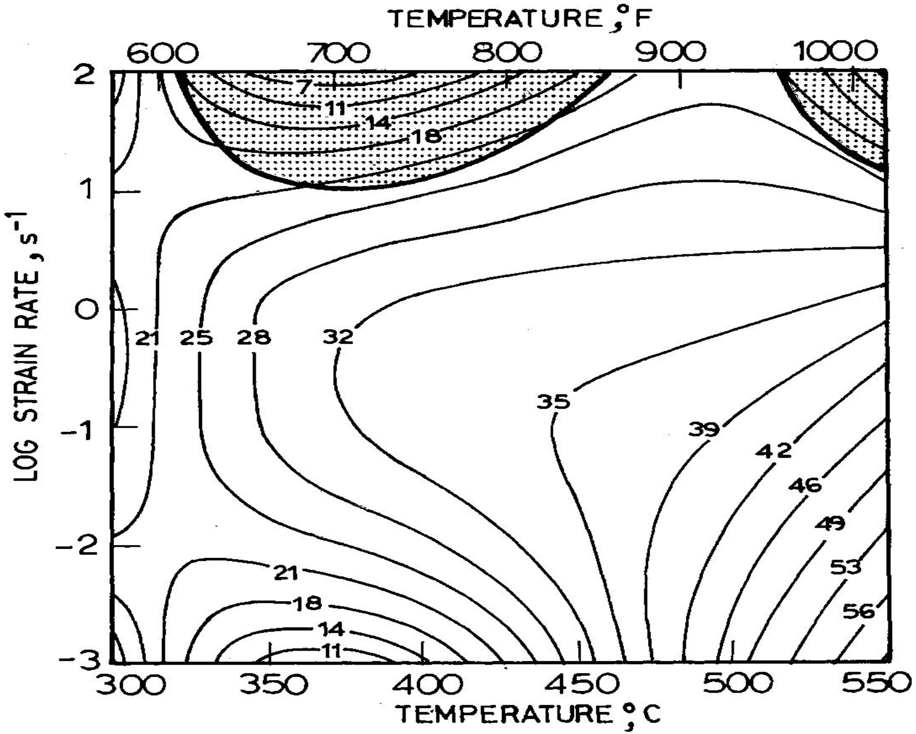


Fig. 1. Processing map for as-cast magnesium at a strain of 0.5. Contour numbers represent percent efficiency of power dissipation. Shaded region corresponds to flow instability.

The map (Fig-1) for as-cast magnesium exhibits the following domains:

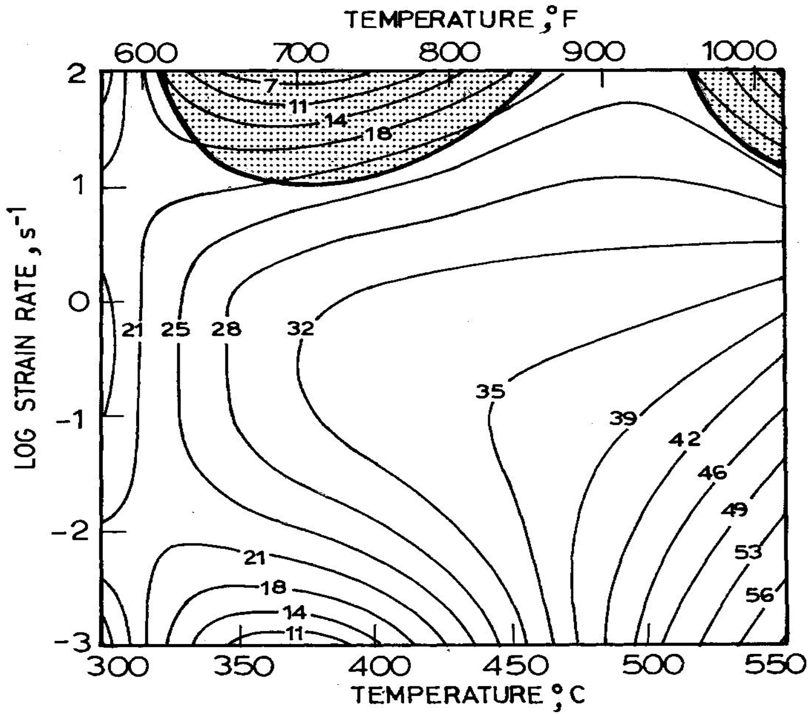
(1) A domain occurring at 425°C and 0.3 s^{-1} with a peak efficiency of 32% represents dynamic recrystallization (DRX) of the metal.

(2) A domain occurring at 550°C and 0.001 s^{-1} with a peak efficiency of about 60% represents wedge cracking. This domain is clearly separated from the DRX domain. Flow instabilities occur at all temperatures and strain rates higher than about 5 s^{-1}. In the lower temperature regime flow localization and twinning are found in the microstructure while at higher temperatures, adiabatic shear bands occur.

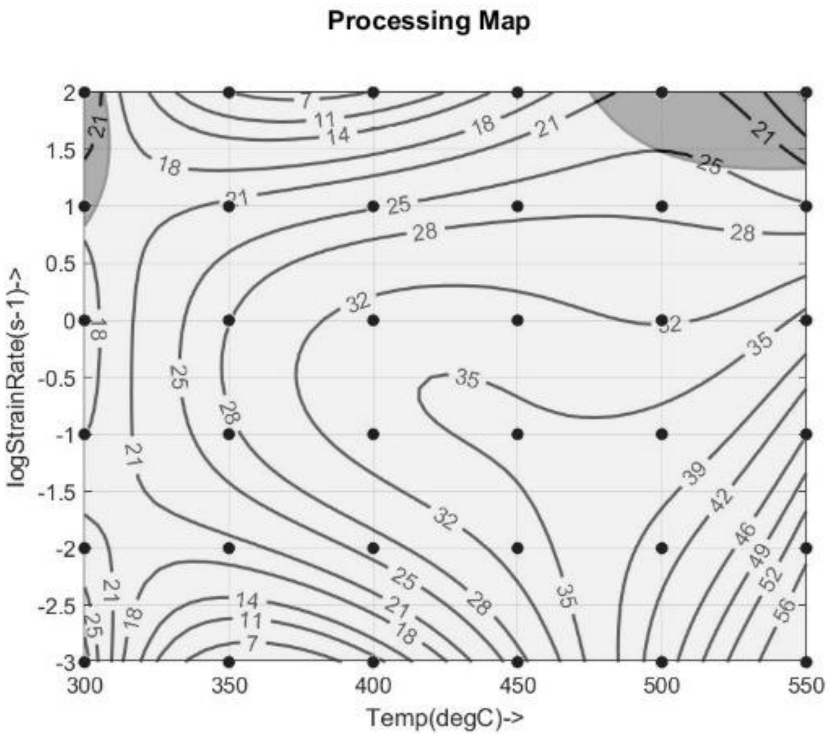
Flow stress values (in MPa) of as-cast magnesium at different temperatures and strain rates for various strains

Strain	Strain Rate, s^{-1}	Temperature, °C					
		300	350	400	450	500	550
0.1	0.001	14.7	13.3	6.1	3.9	3.4	1.5
	0.01	21.0	18.1	9.0	4.4	4.6	3.2
	0.1	29.9	22.8	14.3	10.2	7.3	4.4
	1	39.7	28.9	28.1	18.4	16.9	11.2
	10	43.0	49.5	35.0	30.8	20.0	15.0
	100	77.5	52.0	42.1	32.0	28.6	16.9
0.2	0.001	17.4	13.6	6.7	4.3	3.6	1.6
	0.01	24.8	17.9	9.6	5.6	4.8	3.3
	0.1	34.3	25.2	18.5	12.2	8.5	5.1
	1	46.9	34.3	30.0	28.1	18.2	13.1
	10	55.0	52.0	39.0	33.0	25.3	20.0
	100	84.0	59.0	47.0	38.0	33.5	20.0
0.3	0.001	18.0	14.0	7.0	4.3	2.8	1.3
	0.01	25.0	16.9	9.6	5.9	5.2	3.2
	0.1	33.3	24.6	18.2	12.1	8.6	5.7
	1	46.4	34.9	26.6	19.4	15.5	12.3
	10	52.5	50.0	36.5	30.8	24.5	20.0
	100	77.5	58.5	47.5	38.0	32.8	23.4
0.4	0.001	18.0	13.9	7.3	4.3	2.4	1.1
	0.01	24.0	16.4	9.6	5.7	5.3	2.9
	0.1	31.6	23.5	16.9	11.8	8.8	6.0
	1	44.8	32.9	24.0	17.3	14.0	11.6
	10	46.0	48.0	35.0	29.1	22.8	19.1
	100	72.0	55.8	45.0	37.8	30.7	23.1
0.5	0.001	17.3	14.0	7.2	4.5	2.5	1.1
	0.01	23.5	15.9	9.7	5.5	5.3	3.0
	0.1	30.7	22.4	16.0	11.3	8.6	6.0
	1	43.0	30.1	22.1	15.1	12.8	11.1
	10	44.0	48.0	34.1	27.5	21.0	18.2
	100	65.5	53.5	42.9	33.9	27.3	21.9

Processing map for Mg

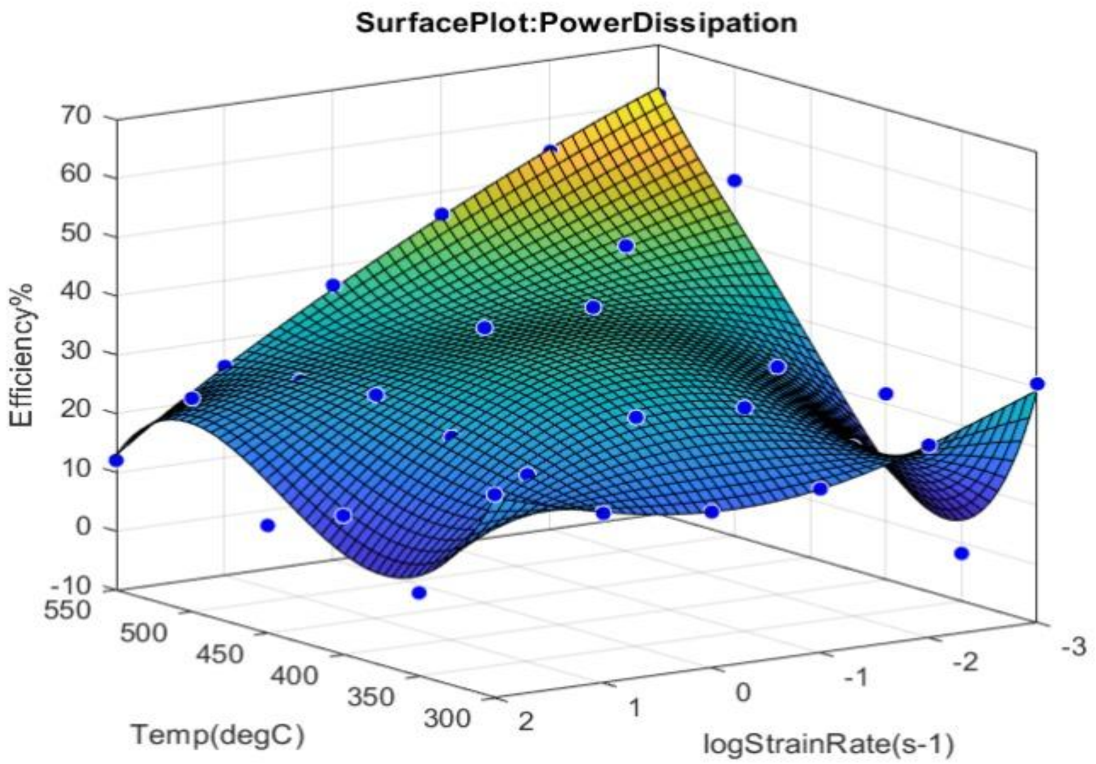


Given map



Our map

3D Power Dissipation map for Mg



Metallurgical Interpretation and Processing Conditions for As-cast Magnesium

Manifestation	Temperature, °C	Strain rate, s^{-1}
Dynamic recrystallization	425	0.3
Wedge cracking	550	0.001
Instabilities (flow localization and twinning)	< 500	> 5
Adiabatic shear bands	> 500	> 5
Optimum Conditions: 425°C and 0.3 s^{-1}		

Processing Map for As cast AZ31

Material: Mg-3Al-1Zn (AZ31) Cast

Composition: Al – 3.1, Zn – 0.98, Mn – 0.2, Si <0.01, Zr <0.002, Fe – 0.002, Bal - Mg.

Prior History: As-cast in permanent mold (AC) at 450^{o}C for 5 hours and furnace cooled (CH).

Introduction: Mg-3Al-1Zn (AZ31) is one of the popular wrought magnesium alloys. Because of its limited ductility at room temperature, processing at high temperatures is essential for bulk metal working of AZ31,

Processing map

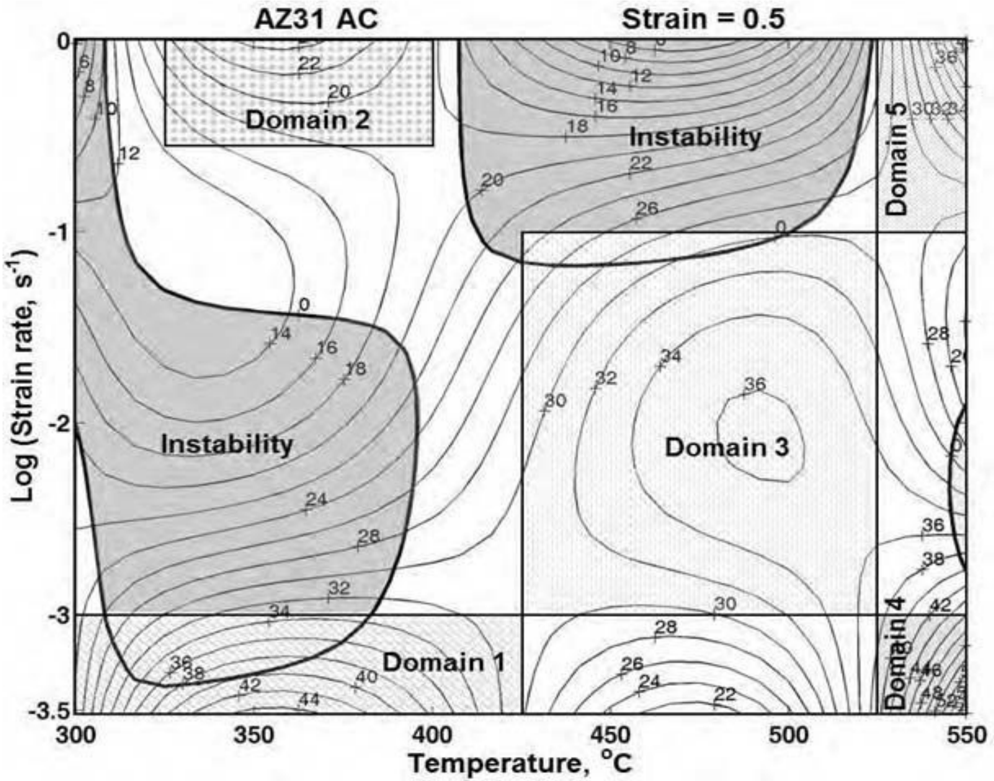


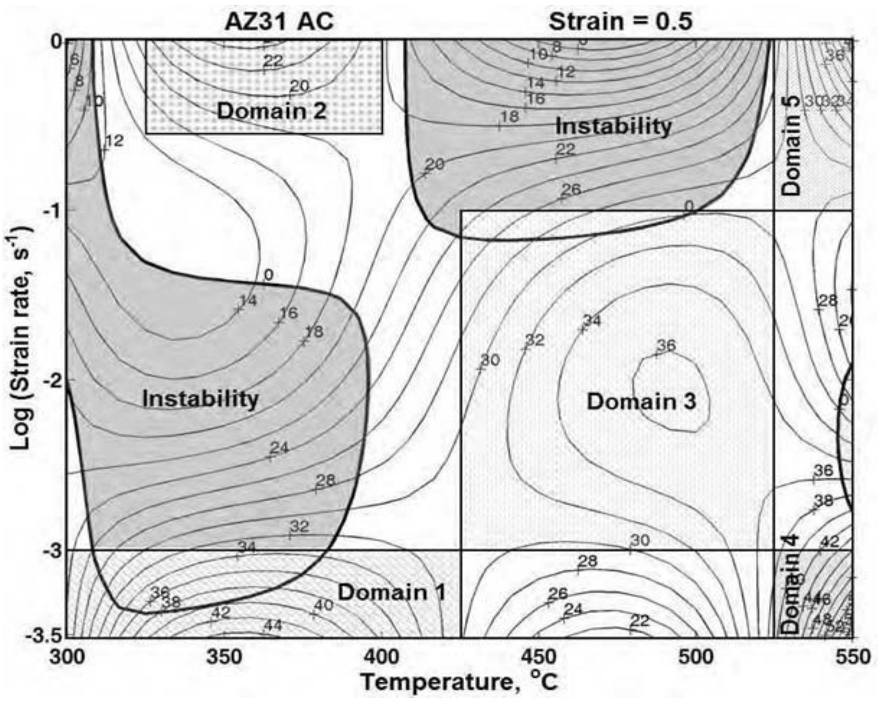
Fig. 2. Processing Maps for AZ31 alloy in as-cast (AC) condition at a strain of 0.5. Numbers represent percent efficiency of power dissipation. The region of flow instability is marked.

processing map for as-cast material (Fig-2) exhibits three workability domains of dynamic recrystallization, in the temperature and strain rate ranges: (1) 300–425 °C and 0.0003–0.001 s^{-1} with a peak efficiency of 44% at 350 °C/ 0.0003 s^{-1}, (2) 325–400 °C and 0.3–1.0 s^{-1} with a peak efficiency of 24% at 350 °C/ 1 s^{-1}, and (3) 425–525 °C and 0.001–0.1 s^{-1} with a peak efficiency of 36% at 500 °C/ 0.01 s^{-1}. In addition, two cracking domains occur at 525 - 550 °C and 0.0003 - 0.001 s^{-1} with a peak efficiency of 58% at 550 °C/0.0003 s^{-1} representing wedge cracking (Domain 4) and at 525 - 550 °C and 0.1 - 1 s^{-1} with a peak efficiency of 44% at 550 °C/1 s^{-1} representing intercrystalline cracking. Flow instability occurs in the temperature range 300-400°C at strain rates higher than 0.001 s^{-1} and in the temperature range 425-525°C at strain rates higher than 0. 1 s^{-1}.

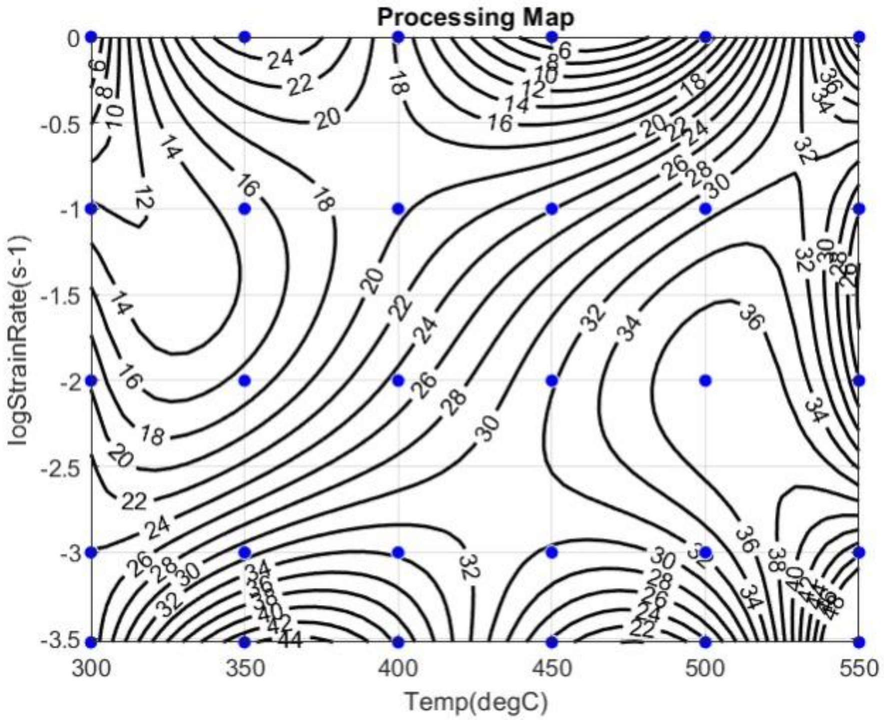
Flow stress in MPa for as-cast AZ31 Magnesium at different temperatures, strain rates and strains.

Strain	Strain Rate, s^{-1}	Temperature, °C					
		300	350	400	450	500	550
0.1	0.0003	63.5	44.8	27.4	18.8	10.9	5.6
	0.001	74.1	47.6	34.5	21.6	13.2	7.7
	0.01	84.9	69.6	45.8	31.5	21.6	11.8
	0.1	105.0	81.8	60.5	44.0	32.9	17.8
	1.0	117.0	98.0	71.5	56.8	46.0	32.6
0.2	0.0003	65.9	41.2	24.2	17.5	10.5	5.1
	0.001	77.3	49.4	33.3	20.8	12.6	7.5
	0.01	96.2	72.3	45.8	31.0	21.1	11.3
	0.1	115.1	90.2	64.0	44.6	32.7	17.0
	1.0	130.0	107.0	82.1	60.2	47.2	30.8
0.3	0.0003	63.2	39.5	22.7	16.7	9.8	4.7
	0.001	72.9	49.4	31.7	20.2	12.0	7.3
	0.01	95.5	69.6	44.4	30.4	20.3	11.0
	0.1	113.4	88.0	63.0	44.0	31.8	16.3
	1.0	128.5	103	81.3	57.5	45.5	28.3
0.4	0.0003	57.1	37.4	21.7	16.1	9.4	4.3
	0.001	66.9	49.4	29.9	19.6	11.4	7.1
	0.01	90.4	65.7	42.7	29.4	19.5	10.8
	0.1	108.8	82.0	60.3	42.5	30.8	15.7
	1.0	122.0	101.0	76.1	53.4	43.3	26.0
0.5	0.0003	53.2	35.5	21.0	15.6	9.2	4.3
	0.001	61.8	49.0	28.1	19.0	10.8	6.9
	0.01	84.1	62.1	40.9	28.4	18.8	10.7
	0.1	102.0	76.2	57.9	41.3	29.7	15.3
	1.0	113.5	95.5	71.7	50.0	41.2	24.4
0.6	0.0003	51.1	34.1	19.8	15.2	9.1	4.2
	0.001	57.8	48.6	26.9	18.7	10.6	6.9
	0.01	77.4	59.5	39.4	27.8	18.4	10.8
	0.1	95.3	70.8	55.5	40.0	28.8	15.1
	1.0	105.5	89.8	68.0	48.0	39.0	23.4

Processing map of AZ31(As-cast)

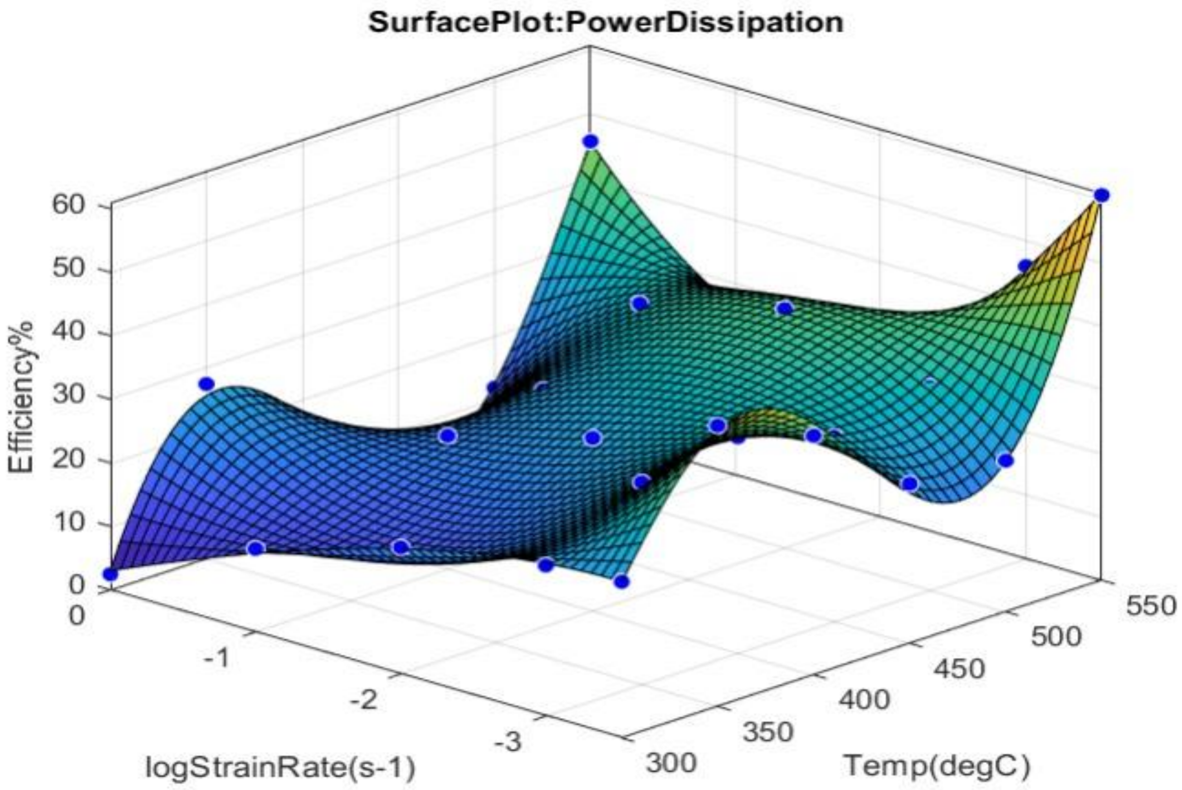


Given map



Our map

3D Power Dissipation map for AZ31(As cast)



Metallurgical Interpretation and Processing Conditions for As-Cast AZ31

Manifestation	Temperature, °C	Strain rate, s^{-1}
DRX (lattice diffusion)	300–425	0.0003–0.001
DRX (g.b. self-diffusion)	325–400	0.3–1.0
DRX (cross-slip)	425–525	0.001–0.1
Wedge cracking	525- 550	0.0003 - 0.001
Intercrystalline cracking	525 - 550	0.1 - 1
FlowInstability regimes	300-400°C	> 0.001
	425-525°C	> 0. 1
Optimum Conditions: 325–400 °C and 0.3–1.0 s^{-1} or 425–525 °C 0.001–0.1 s^{-1}		

Processing Map for AZ31(Hot Rolled)

Material: Mg-3Al-1Zn (AZ31) Hot Rolled

Composition: Al – 3%, Zn – 1%. Mn –0.2%, remainder Mg.

Prior History: Hot rolled 25 mm thick plate of AZ31B magnesium alloy (commercial). Three sets of specimens were machined such that the compression axis was oriented parallel to (1) Rolling Direction (RD), (2) Transverse Direction (TD), or (3) Normal to the Rolling Plane (ND).

Introduction: Rolling of AZ31 plate produces a texture that may be described primarily to consist of the rolling plane is parallel to {0002} and the rolling direction is $\langle 1\ 0\ \bar{1}\ 0 \rangle$. In this section, the effect of rolling texture on the hot workability in the three orthogonal directions, RD, TD and ND are described in terms of its effect on processing maps

Processing map for hot rolled AZ31 (RD)

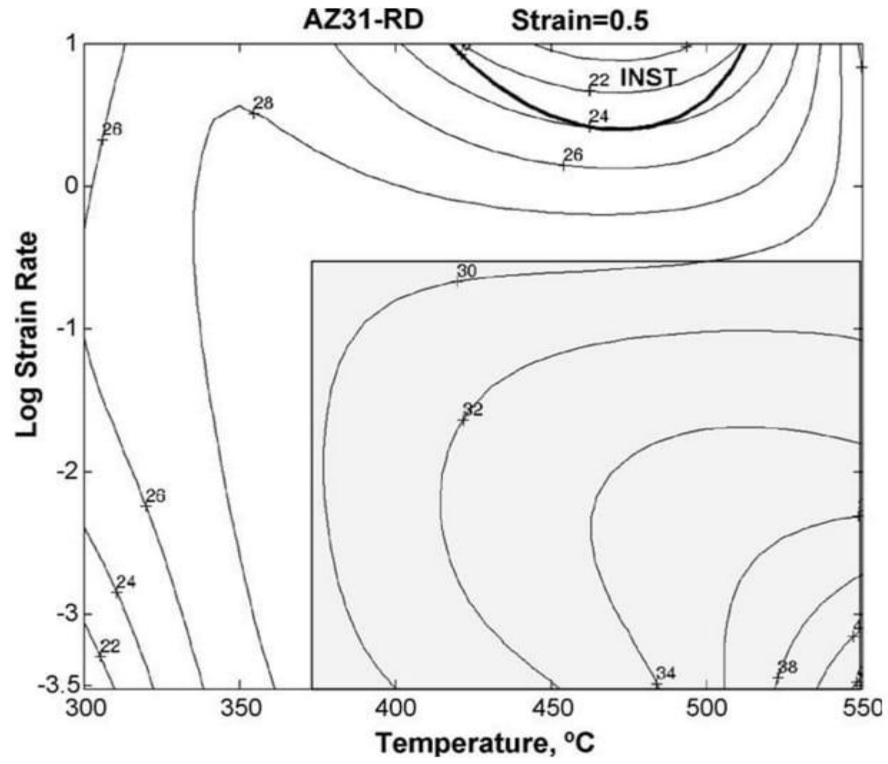
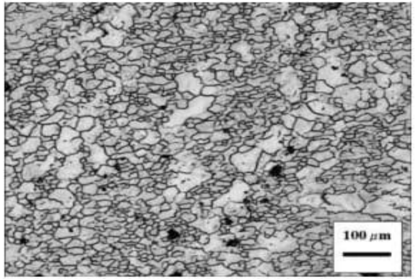


Fig. 3. . Processing Map for Hot Rolled AZ31 RD at a strain of 0.5. Numbers represent per cent efficiency of power dissipation. The region of flow instability is marked.

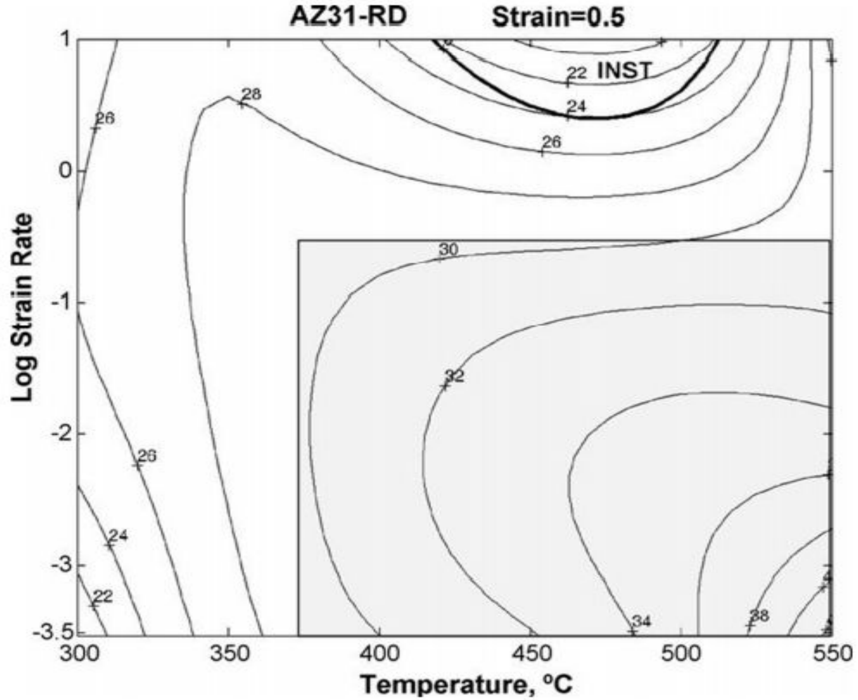


DRX microstructure at 450 °C and 0.001 s^{-1}

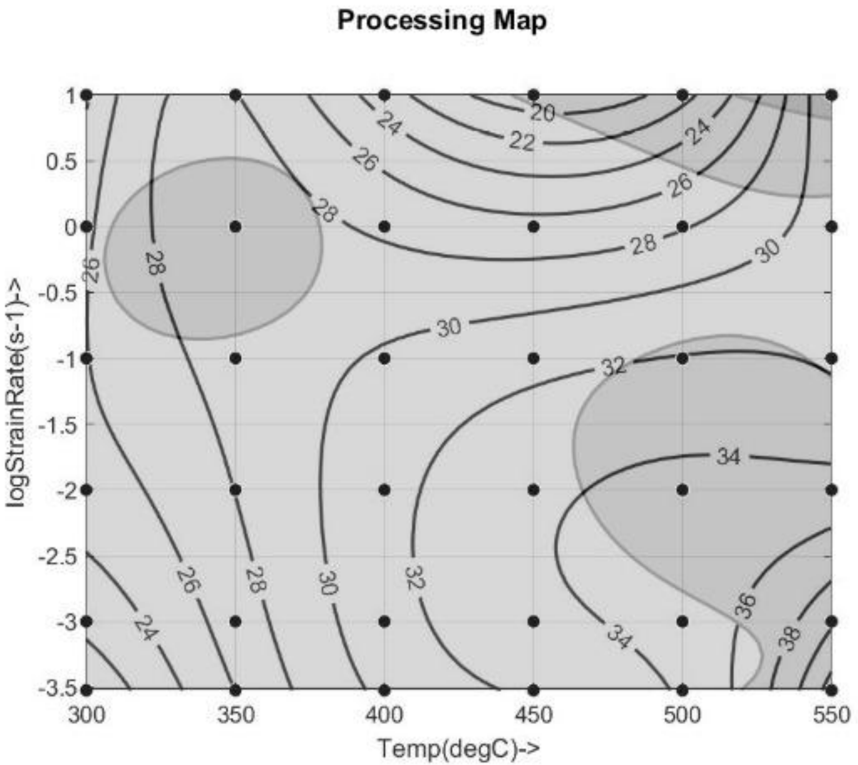
Flow stress in MPa for hot rolled AZ31 Magnesium alloy tested in Rolling Direction, at different temperatures, strain rates and strains.

Strain	Strain Rate, s^{-1}	Temperature, °C					
		300	350	400	450	500	550
0.1	0.0003	36.5	24.0	15.3	8.1	6.1	3.5
	0.001	46.3	32.0	19.4	11.5	8.3	4.9
	0.01	63.9	46.7	31.2	20.7	14.2	9.8
	0.1	86.3	61.8	47.4	32.8	23.2	14.6
	1	111.5	86.5	74.0	47.1	33.9	23.8
	10	146.5	113.0	86.2	69.5	50.0	37.0
0.2	0.0003	33.4	22.8	15.0	8.6	6.0	3.9
	0.001	42.1	29.6	18.2	11.7	8.5	5.0
	0.01	57.5	42.8	29.4	20.0	14.0	9.7
	0.1	84.2	56.6	44.5	31.8	22.9	14.4
	1	140.0	90.2	72.0	46.2	35.4	23.6
	10	194.0	143.3	98.5	68.7	49.0	36.3
0.3	0.0003	32.3	22.1	14.5	8.9	6.7	3.9
	0.001	39.7	27.6	17.2	11.8	8.4	5.1
	0.01	53.3	39.9	28.3	19.3	13.8	9.6
	0.1	77.1	52.6	41.7	30.4	22.4	14.2
	1	127.0	85.0	67.8	44.3	31.8	22.9
	10	183.5	137.3	96.0	65.5	47.0	35.8
0.4	0.0003	32.4	21.4	14.5	9.1	6.8	3.8
	0.001	38.4	26.5	16.2	11.9	8.25	5.1
	0.01	53.0	38.6	27.7	18.9	13.6	9.4
	0.1	74.0	51.5	41.0	29.7	22.6	13.9
	1	114.5	80.0	65.0	43.5	30.7	22.2
	10	158.0	124.0	89.0	62.6	45.0	34.0
0.5	0.0003	33.3	21.2	14.6	9.2	6.9	4.0
	0.001	37.9	26.0	15.6	12.1	8.2	5.1
	0.01	53.0	38.2	27.7	19.3	13.6	9.5
	0.1	73.0	51.0	41.0	29.9	23.3	14.1
	1	106.0	77.0	64.0	42.5	31.0	22.0
	10	144.0	115.0	84.5	62.0	45.0	34.0

Processing map for hot rolled AZ31 Mg(RD)

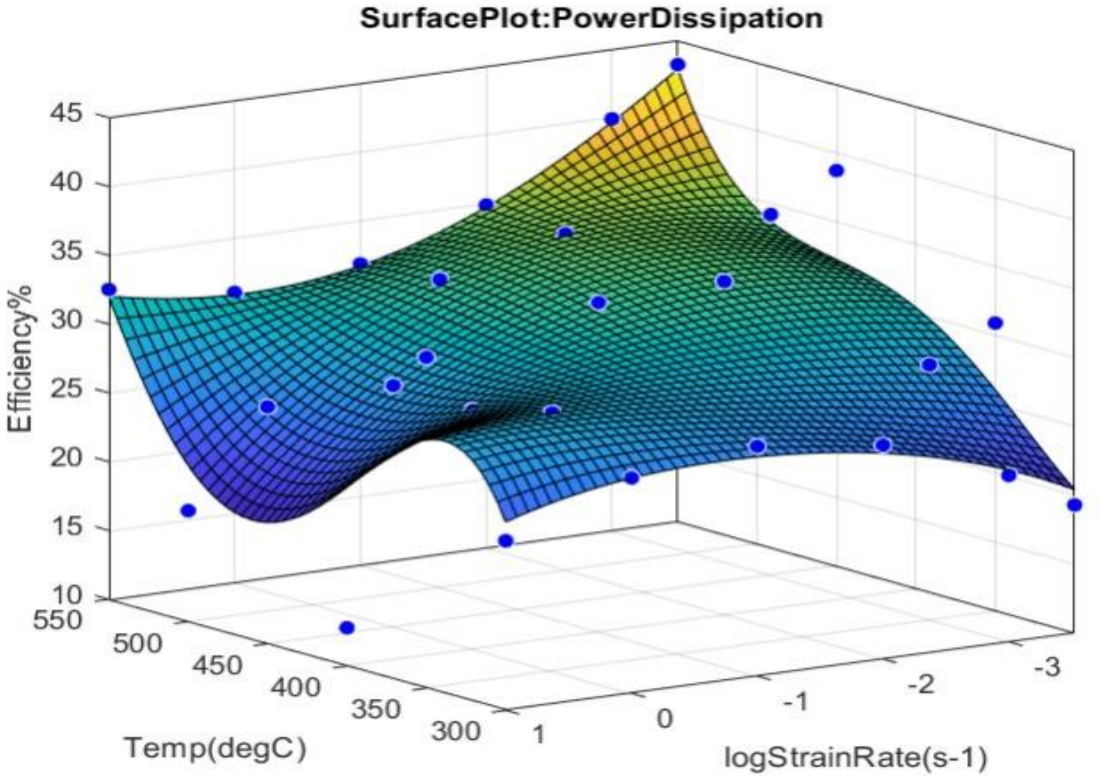


Given map



Our map

3D Power Dissipationmap for AZ31(RD)



Processing map for hot rolled AZ31 (TD)

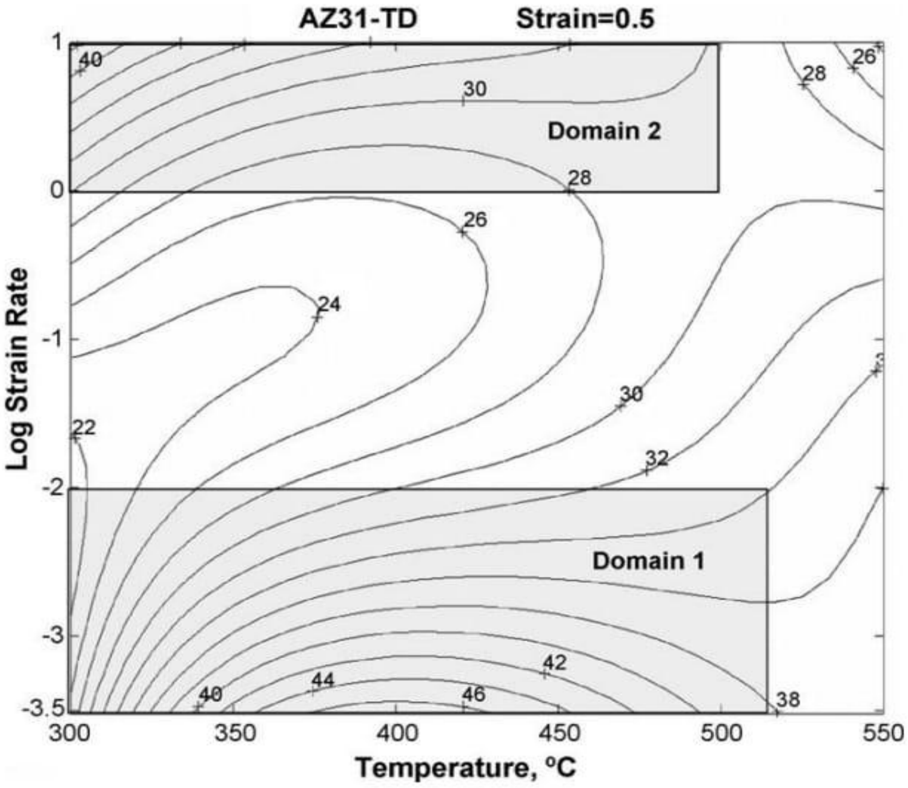
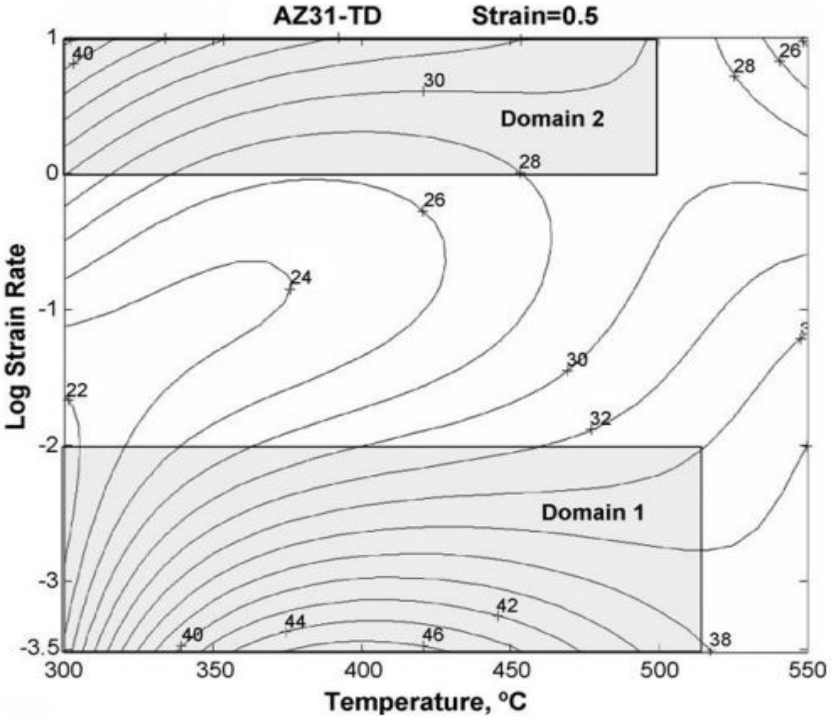


Fig. 4 Processing Map for hot rolled AZ31 TD at a strain of 0.5. Numbers represent per cent efficiency of power dissipation.

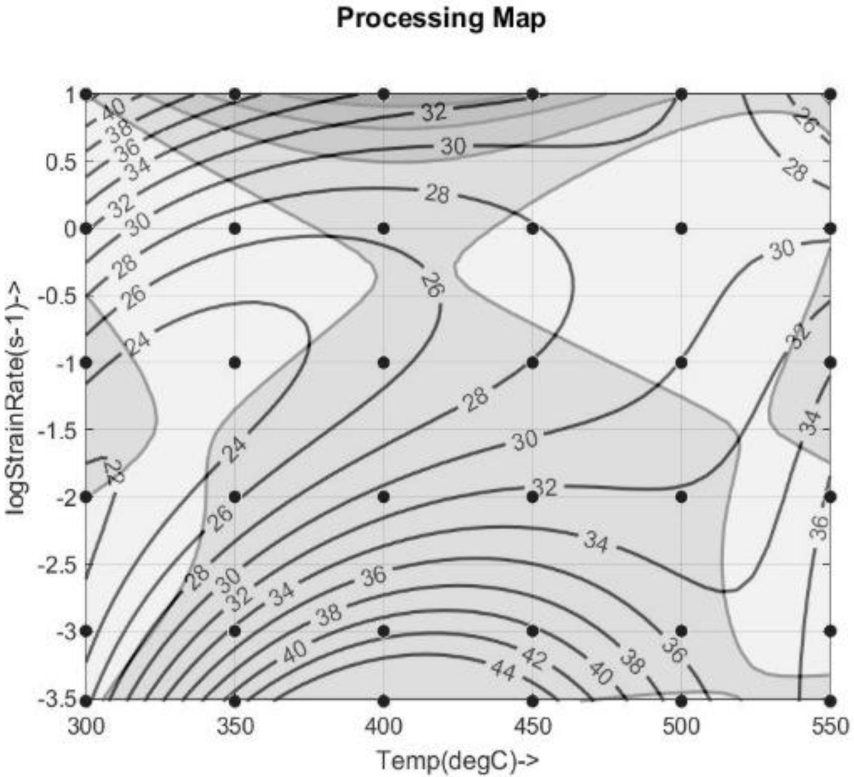
Flow stress in MPa for hot rolled AZ31 Magnesium alloy tested in Transverse Direction, at different temperatures, strain rates and strains.

Strain	Strain Rate, s^{-1}	Temperature, °C					
		300	350	400	450	500	550
0.1	0.0003	40.3	24.1	12.7	6.0	5.1	3.6
	0.001	49.2	31.7	19.2	12.6	7.9	5.7
	0.01	68.5	52.0	34.0	20.6	13.9	9.8
	0.1	90.0	78.8	48.0	33.3	21.2	14.7
	1	122.0	94.4	68.0	48.7	36.1	24.9
	10	161.5	125.4	94.0	70.8	51.6	36.8
0.2	0.0003	37.2	22.8	12.7	6.6	5.5	3.8
	0.001	44.4	29.2	18.7	12.4	8.1	5.9
	0.01	60.1	46.5	31.7	19.9	13.6	9.6
	0.1	86.4	74.8	45.6	32.1	20.8	14.8
	1	142.6	96.3	65.4	47.2	35.7	25.5
	10	220.0	157.5	105.0	70.7	50.3	36.0
0.3	0.0003	35.2	22.0	12.7	7.1	5.8	4.0
	0.001	41.2	27.5	18.2	12.1	8.1	5.9
	0.01	53.8	42.4	30.0	19.0	13.4	9.5
	0.1	78.8	69.5	42.1	30.3	20.2	14.6
	1	126.0	86.7	59.6	43.5	33.7	25.2
	10	213.0	150.6	100.0	66.8	48.1	35.2
0.4	0.0003	34.5	21.3	12.8	7.5	6.1	4.1
	0.001	39.8	26.5	17.8	11.8	8.2	5.8
	0.01	52.6	40.8	29.0	18.5	13.2	9.5
	0.1	73.5	65.8	40.2	29.0	19.6	14.3
	1	110.0	79.5	56.4	41.2	32.2	25.0
	10	194.5	138.0	90.0	63.8	45.7	33.9
0.5	0.0003	34.3	21.1	12.8	7.8	6.3	4.1
	0.001	39.5	26.1	17.8	11.7	8.2	5.8
	0.01	53.2	40.9	28.9	18.5	13.1	9.5
	0.1	71.7	62.9	39.9	28.8	19.5	14.4
	1	101.4	76.3	56.1	40.8	31.3	24.8
	10	175.5	126.8	83.5	61.0	44.9	33.0

Processing map for hot rolled AZ31 (TD)

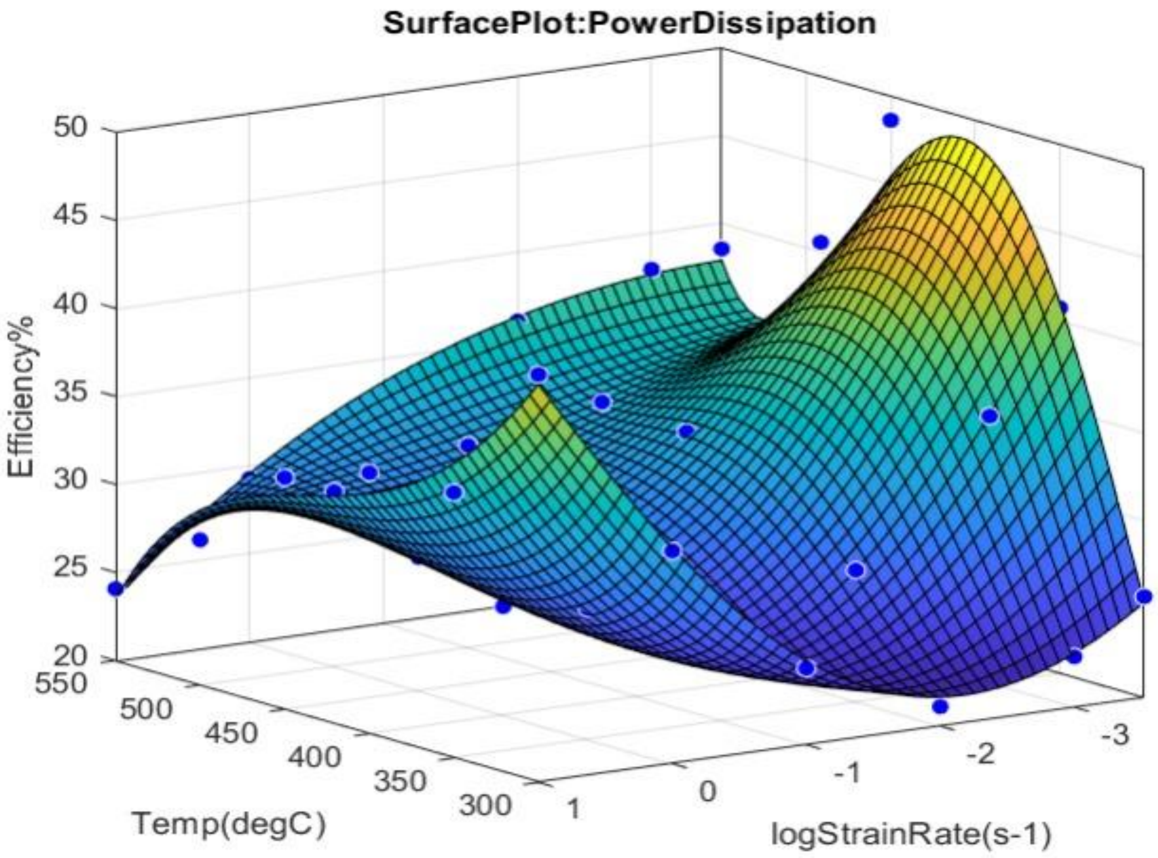


Given map



Our map

3D Power Dissipation map for AZ31(TD)



Processing map for hot rolled AZ31 (ND)

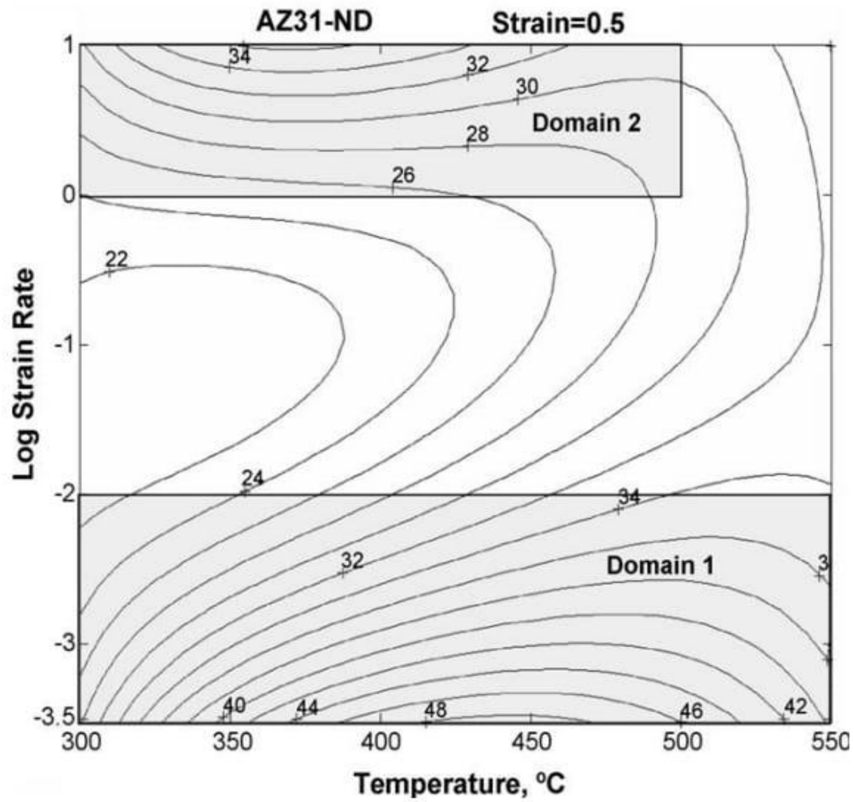
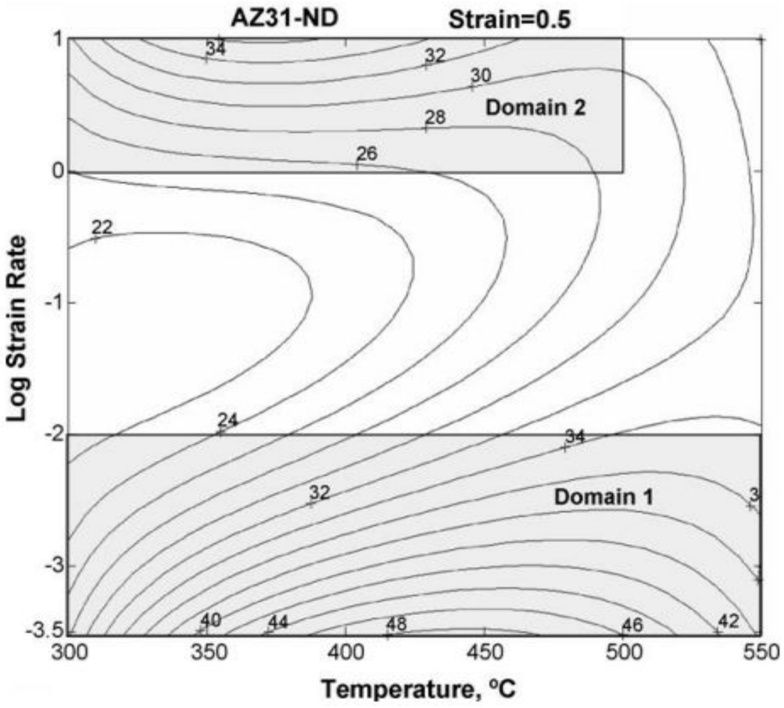


Fig.5 Processing Map for hot rolled AZ31 ND at a strain of 0.5. Numbers represent per cent efficiency of power dissipation.

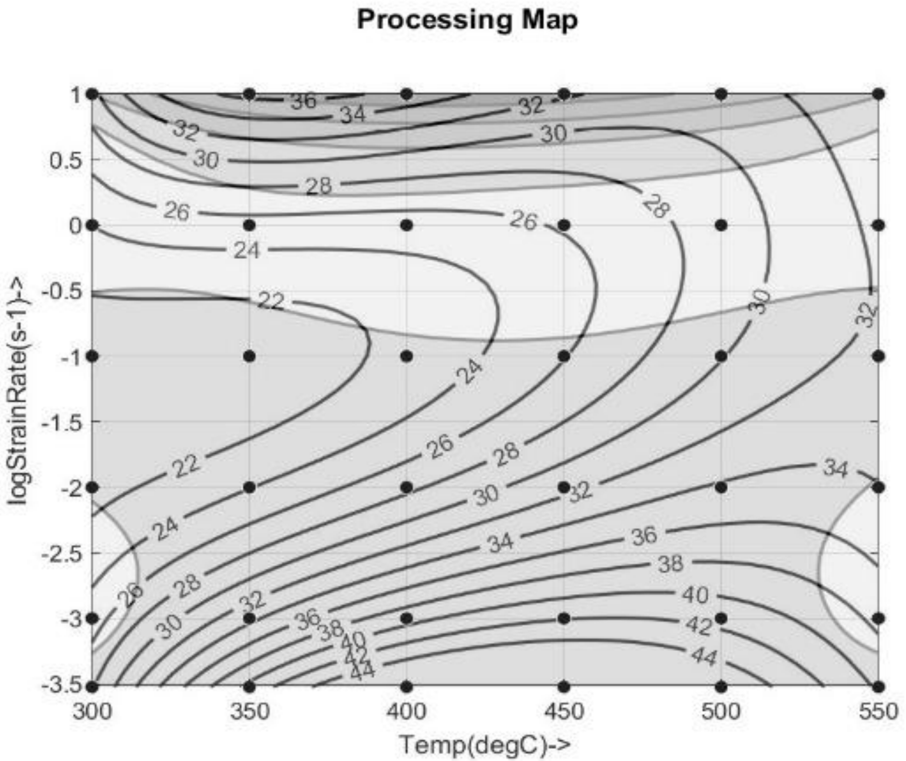
Flow stress values in MPa for hot rolled AZ31 Magnesium alloy tested in Normal Direction, at different temperatures, strain rates and strains.

Strain	Strain Rate, s^{-1}	Temperature, °C					
		300	350	400	450	500	550
0.1	0.0003	38.3	24.3	15.4	9.1	5.6	4.4
	0.001	49.6	32.6	21.3	14.0	9.6	6.0
	0.01	71.5	51.3	35.3	24.0	16.9	11.2
	0.1	105.9	75.1	53.9	39.3	27.2	18.5
	1	157.4	112.0	82.0	63.2	43.7	33.4
	10	186.8	152.0	119.2	88.0	68.7	53.3
0.2	0.0003	36.4	23.8	15.4	9.4	6.0	4.5
	0.001	46.3	31.0	20.9	13.8	9.6	6.1
	0.01	65.4	47.9	34.3	23.4	16.3	10.7
	0.1	92.6	66.8	49.7	37.0	25.9	17.4
	1	143.4	98.2	73.0	56.7	40.8	30.0
	10	198.5	157.8	116.8	84.0	64.6	49.4
0.3	0.0003	34.5	23.1	15.2	9.4	6.2	4.4
	0.001	43.9	30.3	20.6	13.5	9.5	6.0
	0.01	59.8	45.5	33.8	22.6	15.7	10.2
	0.1	81.6	61.2	46.9	35.2	24.5	16.3
	1	124.0	86.8	65.2	51.4	36.8	27.2
	10	165.0	140.0	106.8	76.8	58.4	43.8
0.4	0.0003	32.8	22.4	15.0	9.3	6.2	4.4
	0.001	42.3	29.3	19.9	13.2	9.2	6.0
	0.01	55.9	43.7	33.3	22.08	15.1	9.9
	0.1	71.9	57.6	45.2	33.8	23.5	15.5
	1	111.0	80.5	60.5	48.8	34.5	25.3
	10	155.0	128.0	96.5	71.5	53.5	39.0
0.5	0.0003	31.8	22.0	14.6	9.2	6.2	4.3
	0.001	41.3	28.5	19.6	13.0	9.0	5.8
	0.01	53.3	42.3	32.6	21.5	14.7	9.5
	0.1	65.0	55.1	43.6	32.8	22.8	14.9
	1	99.0	75.0	57.0	46.6	33.0	23.8
	10	130.0	111.5	90.0	66.5	50.4	36.8

Processing map for hot rolled AZ31 (ND)

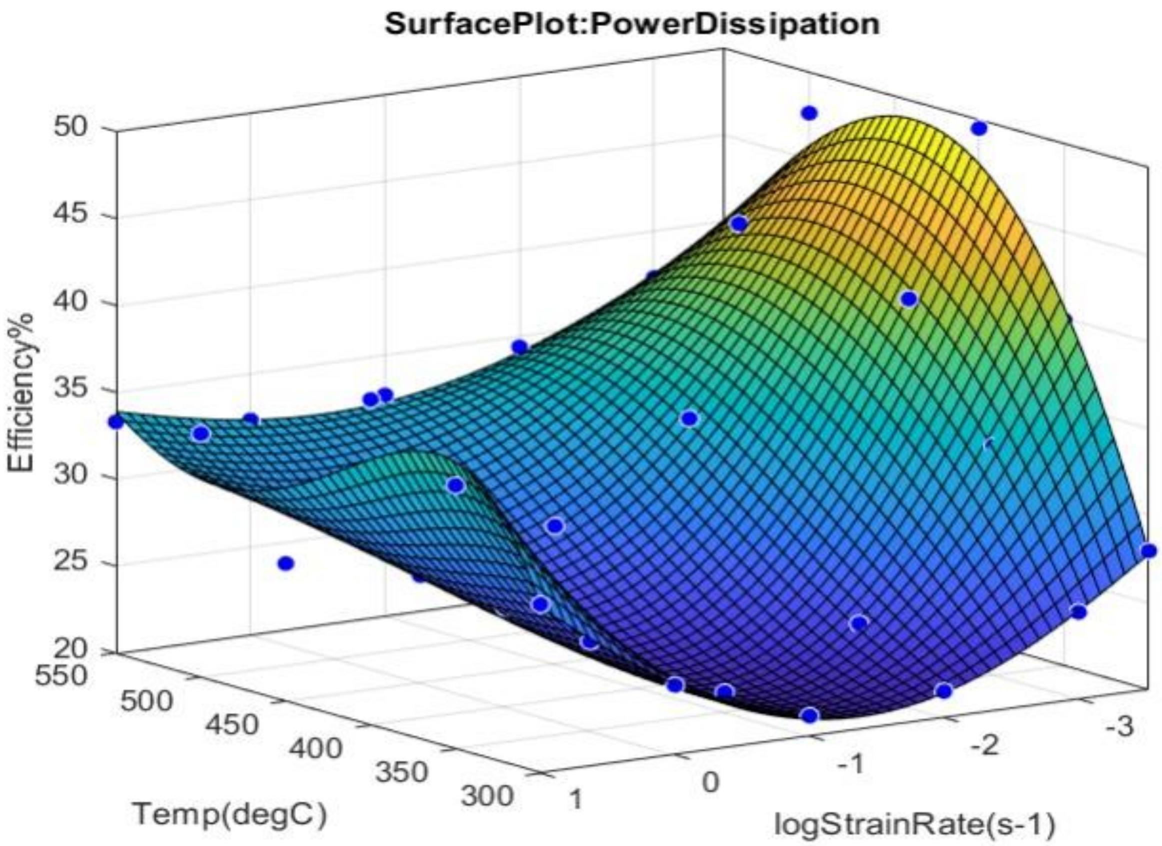


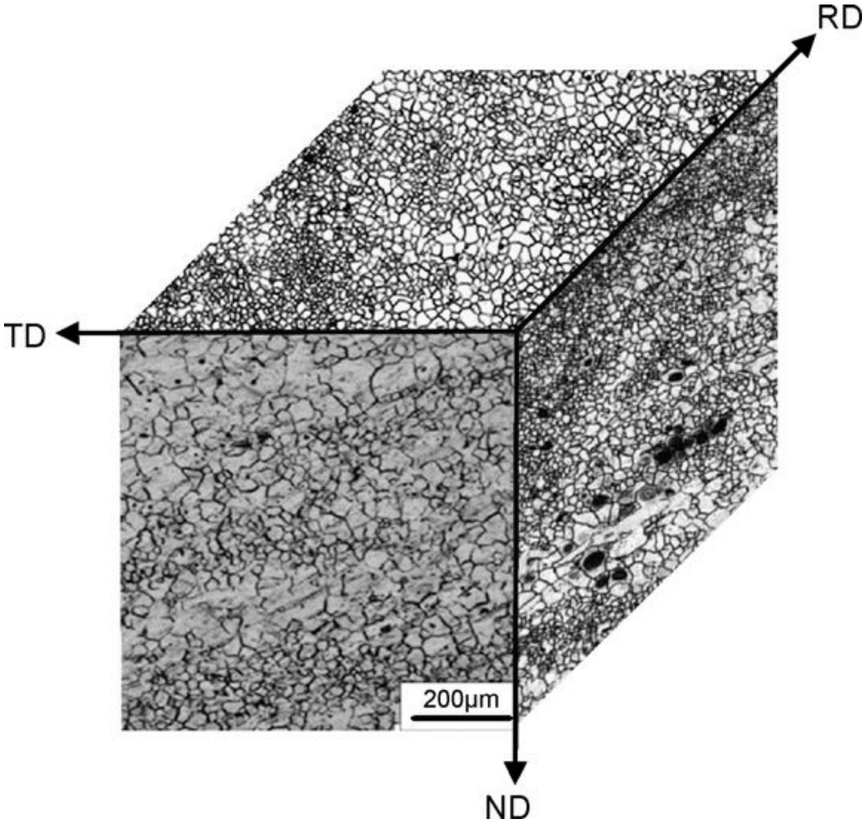
Given map



Our map

3D Power Dissipation map for AZ31(ND)





Microstructures of as-received hot-rolled AZ31 plate recorded on the three planes perpendicular to RD, TD, or ND.

Metallurgical Interpretation and Processing Conditions for hot rolled AZ31 RD

Manifestation	Temperature, °C	Strain rate, s^{-1}
DRX	350 – 550	0.0003 – 0.1
Flow instability	400 – 500	> 1
Optimum Conditions: 500 °C and 0.001 s^{-1}		

Metallurgical Interpretation and Processing Conditions for hot rolled AZ31 TD

Manifestation	Temperature, °C	Strain rate, s^{-1}
DRX (Lattice self-diffusion)	300 – 500	0.0003 – 0.01
DRX (grain boundary self-diffusion)	300 – 400	0.1 – 10
Optimum Conditions: 400 °C and 0.0003 s^{-1} or 300 °C and 10 s^{-1}		

Metallurgical Interpretation and Processing Conditions for hot rolled AZ31 ND

Manifestation	Temperature, °C	Strain rate, s^{-1}
DRX (Lattice self-diffusion)	300 – 550	0.0003 – 0.01
DRX (g.b. self-diffusion)	300 – 450	0.1 – 10
Optimum Conditions: 450 °C and 0.0003 s^{-1} or 375 °C and 10 s^{-1}		

Conclusion

The processing maps on magnesium alloys have indicated the following general trends.

- Mg and Mg-Zn-Mn alloys may be forged in the temperature range 450-500°C using a hydraulic press (0.1 s^{-1}). At higher strain rates, as-cast materials exhibit flow localization and will have to be first press forged to dynamically recrystallize the material, before hot rolling.

- Processing maps on rolled AZ31 magnesium plate have been studied in the range 300–550 ◦C and 0.0003–10 s^{-1} by hot compression of specimens parallel to the rolling direction (RD), the transverse direction (TD), or the normal direction (ND). Hot deformation behavior is anisotropic and the RD orientation is in higher workability than other two orientations.

References

- Processing map for hot working of as-cast magnesium, O. Sivakesavam, I.S. Rao and Y.V.R.K. Prasad, Mat. Sci. Tech. 9(1993)805.
- Hot workability, microstructural control and rate-controlling mechanisms in cast-homogenized AZ31 magnesium alloy, Y.V.R.K.Prasad and K.P.Rao, Advanced Engineering Materials 11(3)(2009)182-188.
- Processing maps for hot deformation of rolled AZ31 magnesium alloy plate: Anisotropy of hot workability, Y.V.R.K. Prasad and K.P. Rao, Materials Science and Engineering A 487 (2008) 316-327.

Thank you!

```
values=readtable('ayush.txt');
values.Properties.VariableNames={'Strain','StrainRate','T1','T2','T3','T4','T5','T6'}
```

values = 30×8 table

	Strain	StrainRate	T1	T2	T3	T4	T5	T6
1	0.1000	0.0010	14.7000	13.3000	6.1000	3.9000	3.4000	1.5000
2	0.1000	0.0100	21.0000	18.1000	9.0000	4.4000	4.6000	3.2000
3	0.1000	0.1000	29.9000	22.8000	14.3000	10.2000	7.3000	4.4000
4	0.1000	1.0000	39.7000	28.9000	28.1000	18.4000	16.9000	11.2000
5	0.1000	10.0000	43.0000	49.5000	35.0000	30.8000	20.0000	15.0000
6	0.1000	100.0000	77.5000	52.0000	42.1000	32.0000	28.6000	16.9000
7	0.2000	0.0010	17.4000	13.6000	6.7000	4.3000	3.6000	1.6000
8	0.2000	0.0100	24.8000	17.9000	9.6000	5.6000	4.8000	3.3000
9	0.2000	0.1000	34.3000	25.2000	18.5000	12.2000	8.5000	5.1000
10	0.2000	1.0000	46.9000	34.3000	30.0000	28.1000	18.2000	13.1000
11	0.2000	10.0000	55.0000	52.0000	39.0000	33.0000	25.3000	20.0000
12	0.2000	100.0000	84.0000	59.0000	47.0000	38.0000	33.5000	20.0000
13	0.3000	0.0010	18.0000	14.0000	7.0000	4.3000	2.8000	1.3000
14	0.3000	0.0100	25.0000	16.9000	9.6000	5.9000	5.2000	3.2000
15	0.3000	0.1000	33.3000	24.6000	18.2000	12.1000	8.6000	5.7000
16	0.3000	1.0000	46.4000	34.9000	26.6000	19.4000	15.5000	12.3000
17	0.3000	10.0000	52.5000	50.0000	36.5000	30.8000	24.5000	20.0000
18	0.3000	100.0000	77.5000	58.5000	47.5000	38.0000	32.8000	23.4000
19	0.4000	0.0010	18.0000	13.9000	7.3000	4.3000	2.4000	1.1000
20	0.4000	0.0100	24.0000	16.4000	9.6000	5.7000	5.3000	2.9000
21	0.4000	0.1000	31.6000	23.5000	16.9000	11.8000	8.8000	6.0000
22	0.4000	1.0000	44.8000	32.9000	24.0000	17.3000	14.0000	11.6000
23	0.4000	10.0000	46.0000	48.0000	35.0000	29.1000	22.8000	19.1000
24	0.4000	100.0000	72.0000	55.8000	45.0000	37.8000	30.7000	23.1000
25	0.5000	0.0010	17.3000	14.0000	7.2000	4.5000	2.5000	1.1000
26	0.5000	0.0100	23.5000	15.9000	9.7000	5.5000	5.3000	3.0000
27	0.5000	0.1000	30.7000	22.4000	16.0000	11.3000	8.6000	6.0000
28	0.5000	1.0000	43.0000	30.1000	22.1000	15.1000	12.8000	11.1000
29	0.5000	10.0000	44.0000	48.0000	34.1000	27.5000	21.0000	18.2000
30	0.5000	100.0000	65.5000	53.5000	42.9000	33.9000	27.3000	21.9000

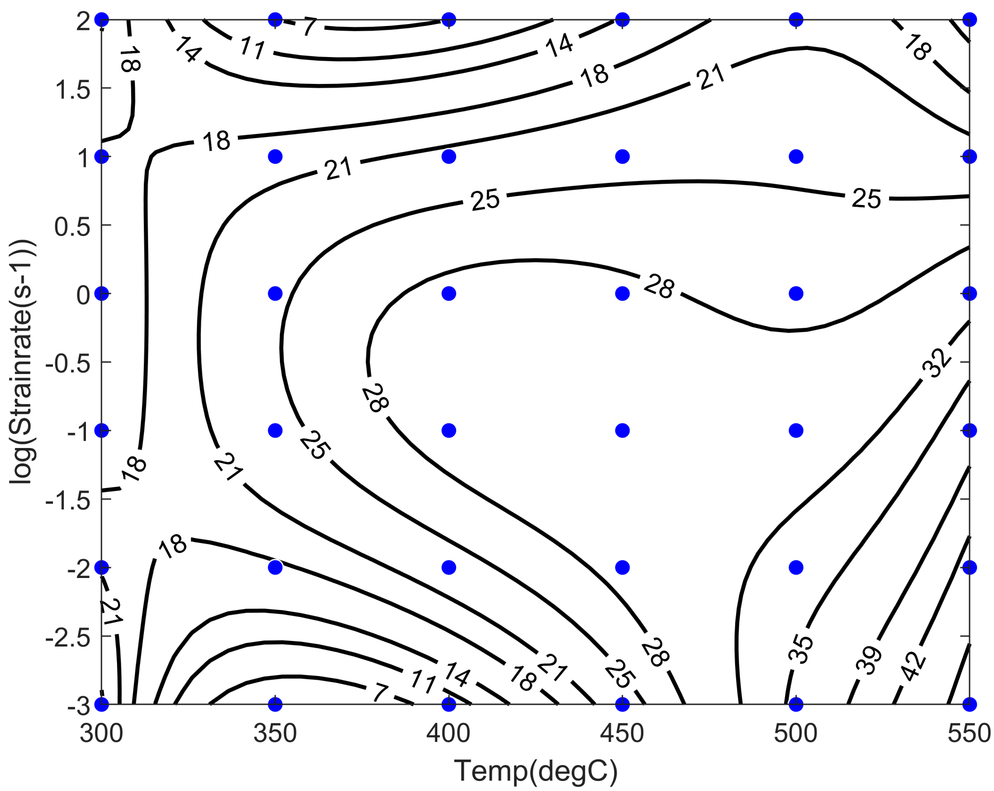
```
ar=table2array(values);
```

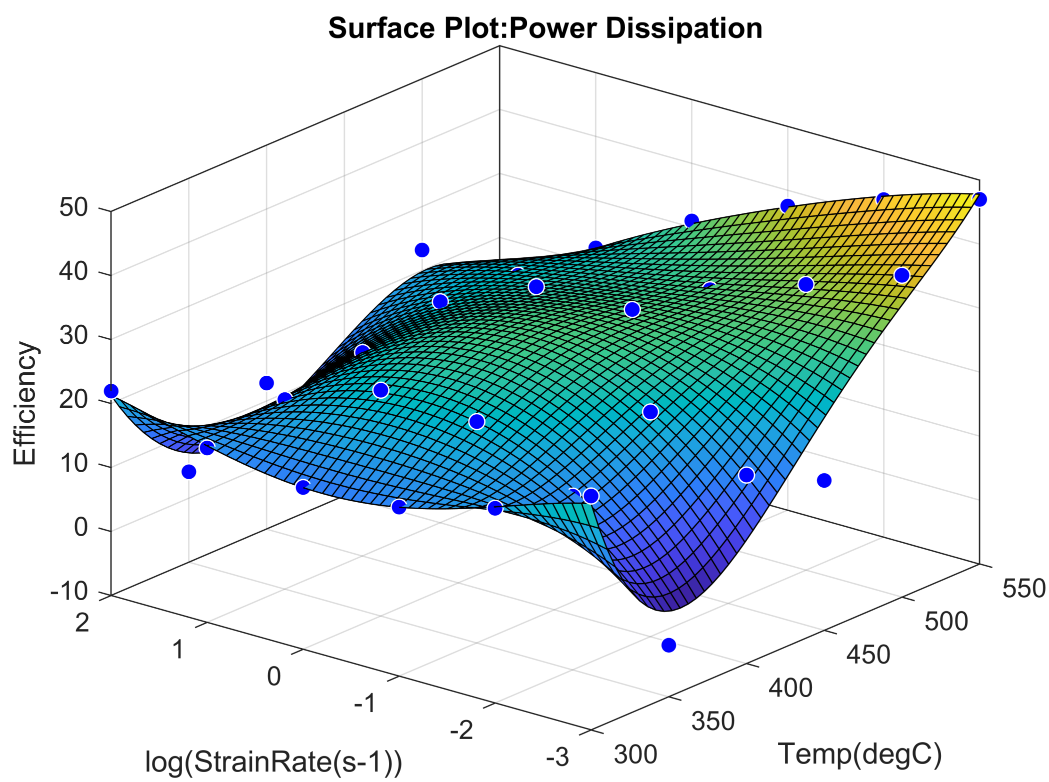
```
sig=ar(25:30,3:end);
logsig=log10(sig);
str=ar(25:30,2:2);
logstr=log10(str);
m=zeros(6,6);
for i=1:6
    p=polyfit(logstr,logsig(:,i),3);
    q=polyder(p);
    for j=1:6
        m(j,i)=polyval(q,logstr(j));
    end
end
eff=((2*m)./(2*m+1))*100;
n=m./(m+1);
T=300:50:550;
logn=log10(n);
tmp=zeros(6,6);
for i=1:6
    p=polyfit(logstr,logn(:,i),3);
    q=polyder(p);
    for j=1:6
        tmp(j,i)=polyval(q,logstr(j));
    end
end
ins=tmp+m;%instability values

[xData, yData, zData] = prepareSurfaceData( T, logstr, eff );
ft = fittype( 'poly45' );
[fitresult, ~] = fit( [xData, yData], zData, ft, 'Normalize', 'on' );
figure( 'Name', 'untitled fit 1' );
plot( fitresult, [xData, yData], zData );
xlabel( 'Temp(degC)', 'Interpreter', 'none' );
ylabel( 'log(StrainRate(s-1))', 'Interpreter', 'none' );
zlabel( 'Efficiency', 'Interpreter', 'none' );
grid off
view( -51.0, 29.1 );
grid on

ft = fittype( 'poly45' );
title('Surface Plot:Power Dissipation')
% Fit model to data.
[fitresult, ~] = fit( [xData, yData], zData, ft, 'Normalize', 'on' );

figure( 'Name', 'untitled fit 1' );
h=plot( fitresult, [xData, yData], zData, 'Style', 'Contour' );
% Label axes
xlabel( 'Temp(degC)', 'Interpreter', 'none' );
ylabel( 'log(Strainrate(s-1))', 'Interpreter', 'none' );
grid off
clabel(h(1).ContourMatrix, h(1),'FontSize',10,'Color','Black');
set(h(1),'LineWidth',1.5,'Fill','off');
set(h(1),'LevelList',[7,11,14,18,21,25,28,32,35,39,42,46,49,52,56]);
fig=gcf;
saveas(fig,'eff.jpg');
```





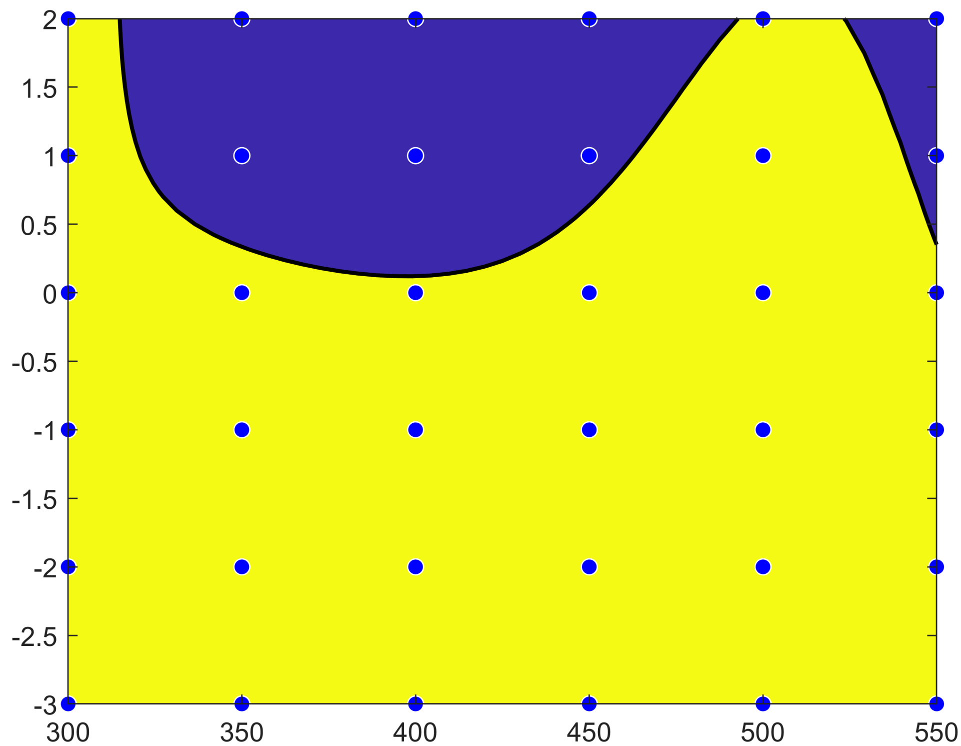

```
%% Fit: 'untitled fit 1'.
[xData, yData, zData] = prepareSurfaceData( T, logstr, ins );
```

```
Warning: Using only the real component of complex data.
```

```
% Set up fittype and options.
ft = fittype( 'poly44' );

% Fit model to data.
[fitresult, gof] = fit( [xData, yData], zData, ft, 'Normalize', 'on' );

% Make contour plot.
figure( 'Name', 'untitled fit 1' );
h = plot( fitresult, [xData, yData], zData, 'Style', 'Contour' );
% Label axes
xlabel( ' ','Interpreter', 'none' );
ylabel( ' ','Interpreter', 'none' );
grid off
set(h(1),'LineWidth',1.5,'LevelStep',1.5);
fig=gcf;
saveas(fig,'ins.jpg');
```




```
fig1 = imread('eff.jpg');
fig2 = imread('ins.jpg');
fusionimage=imfuse(fig1,fig2,'falsecolor','Scaling','joint');
op=rgb2gray(fusionimage);
imshow(op);
title('Processing Map',"FontSize",15)
```

Processing Map