Creep Data Analysis

Importing creep data as comma separated value(csv) file

In [71]:
```
import warnings
warnings.filterwarnings('ignore')
```

In [72]:
```
import numpy as np
import pandas as pd
creep=pd.read_csv('creepdata.csv')
```

In [73]:
```
# print the creep data
creep
```

Out[73]:

	Temperature	Load	Time Period(Hour)	Time Period(Year)	CEEQ	Category
0	500	110	0.00	0.000000	0.000000e+00	A
1	500	110	0.05	0.000006	0.000000e+00	A
2	500	110	0.10	0.000011	1.460000e-05	A
3	500	110	0.15	0.000017	2.922200e-05	A
4	500	110	0.20	0.000023	4.380000e-05	A
5	500	110	0.30	0.000034	7.300000e-05	A
6	500	110	0.50	0.000057	1.314700e-04	A
7	500	110	0.90	0.000103	2.482770e-04	A
8	500	110	1.70	0.000194	4.817410e-04	A
9	500	110	3.30	0.000377	9.480650e-04	A
10	500	110	6.50	0.000742	1.878310e-03	A
11	500	110	12.90	0.001473	3.729230e-03	A
12	500	110	25.70	0.002934	7.322550e-03	A
13	500	110	51.30	0.005856	1.423770e-02	A
14	500	110	89.70	0.010240	2.406410e-02	A
15	500	110	147.30	0.016815	3.773830e-02	A
16	500	110	233.70	0.026678	5.627380e-02	A
17	500	110	363.30	0.041473	8.062980e-02	A
18	500	110	557.70	0.063664	1.115460e-01	A
19	500	110	849.30	0.096952	1.494010e-01	A
20	500	110	1140.90	0.130240	1.813200e-01	A
21	500	110	1432.50	0.163527	2.088780e-01	B
22	500	110	1724.10	0.196815	2.331050e-01	B
23	500	110	2161.50	0.246747	2.639680e-01	B
24	500	110	2778.46	0.317176	2.999710e-01	B
25	500	110	3395.42	0.387605	3.306070e-01	B
26	500	110	4012.38	0.458034	3.572330e-01	B
27	500	110	4629.34	0.528463	3.807590e-01	B
28	500	110	5554.78	0.634107	4.108870e-01	C
29	500	110	6942.95	0.792574	4.480900e-01	C
...	...	...	...	...	...	...
1210	100	70	164685.00	18.799658	9.205660e-02	A
1211	100	70	245289.00	28.001027	1.166300e-01	A
1212	100	70	262800.00	30.000000	1.216990e-01	A
1213	100	60	0.00	0.000000	0.000000e+00	A
1214	100	60	0.05	0.000006	0.000000e+00	A
1215	100	60	0.10	0.000011	2.930000e-14	A
1216	100	60	0.15	0.000017	5.850000e-14	A
1217	100	60	0.20	0.000023	8.780000e-14	A
1218	100	60	0.30	0.000034	1.460000e-13	A
1219	100	60	0.50	0.000057	2.630000e-13	A
1220	100	60	0.90	0.000103	4.980000e-13	A
1221	100	60	1.70	0.000194	9.660000e-13	A
1222	100	60	3.30	0.000377	1.900000e-12	A
1223	100	60	6.50	0.000742	3.780000e-12	A
1224	100	60	12.90	0.001473	7.520000e-12	A
1225	100	60	25.70	0.002934	1.500000e-11	A
1226	100	60	51.30	0.005856	3.000000e-11	A
1227	100	60	102.50	0.011701	6.000000e-11	A
1228	100	60	204.90	0.023390	1.200000e-10	A
1229	100	60	409.70	0.046769	2.400000e-10	A
1230	100	60	819.30	0.093527	4.800000e-10	A
1231	100	60	1638.50	0.187043	9.590000e-10	A
1232	100	60	3276.90	0.374075	1.920000e-09	A
1233	100	60	6553.70	0.748139	3.840000e-09	A
1234	100	60	13107.30	1.496267	7.670000e-09	A
1235	100	60	26214.50	2.992523	1.530000e-08	A
1236	100	60	52428.90	5.985034	3.070000e-08	A
1237	100	60	104858.00	11.970091	6.140000e-08	A
1238	100	60	209715.00	23.940068	1.230000e-07	A
1239	100	60	262800.00	30.000000	1.540000e-07	A

1240 rows × 6 columns

Analysing the Data Set

The creep data set has 1240 rows and 6 columns

In [74]:
```
creep.shape
```

Out[74]:
```
(1240, 6)
```

In [75]:
```
creep.columns
```

Out[75]:
```
Index(['Temperature', 'Load', 'Time Period(Hour)', 'Time Period(Year)', 'CEEQ',
       'Category'],
      dtype='object')
```

In [76]:
```
# check the types of data stored under each column
creep.dtypes
```

Out[76]:
```
Temperature            int64
Load                   int64
Time Period(Hour)    float64
Time Period(Year)    float64
CEEQ                 float64
Category              object
dtype: object
```

Simulations were run for 5 different temperatures in degree celsius

In [77]:
```
print(creep.Temperature.unique())
```

```
[500 400 300 200 100]
```

In [78]:
```
print(creep.Temperature.value_counts())
```

```
500    266
400    251
300    251
200    250
100    222
Name: Temperature, dtype: int64
```

Simulations were run for 7 different load in MPa

In [79]:
```
print(creep.Load.unique())
```

```
[110 100  90  80  70  60  50]
```

In [80]:
```
print(creep.Load.value_counts())
```

```
110    249
100    222
90     198
80     172
70     152
60     139
50     108
Name: Load, dtype: int64
```

There is no missing values in the data set

In [81]:
```
creep.isnull().sum()
```

Out[81]:
```
Temperature          0
Load                 0
Time Period(Hour)    0
Time Period(Year)    0
CEEQ                 0
Category             0
dtype: int64
```

In [82]:
```
creep.Category.describe()
```

Out[82]:
```
count     1240
unique       6
top          A
freq       912
Name: Category, dtype: object
```

The highest simulated creep value is 1.21 mm for the node shows the maximum creep value at a temperature of 500 degree Celcius, 110 MPa load when the simulation was run for 262800 hours.

The whole data set is divided into 6 categories according to creep values.

Category	CEEQ(mm)
A	0-.2
B	.2-.4
C	.4-.6
D	.6-.8
F	.8-1
E	1-1.2

In [83]:
```
# the number of CEEQ value in each category
creep.Category.value_counts()
```

Out[83]:
```
A    912
B    136
C     96
D     58
E     32
F      6
Name: Category, dtype: int64
```

In [84]:
```
# let's sort the data set according to CEEQ value descending
creep.sort_values('CEEQ', ascending=False).head(20)
```

Out[84]:

	Temperature	Load	Time Period(Hour)	Time Period(Year)	CEEQ	Category
52	500	110	262800.0	30.000000	1.210420	F
51	500	110	246570.0	28.147260	1.191960	F
50	500	110	214567.0	24.493950	1.153700	F
49	500	110	182565.0	20.840753	1.111160	F
48	500	110	150562.0	17.187443	1.063000	F
47	500	110	127900.0	14.600457	1.023460	F
314	400	110	262800.0	30.000000	0.995481	E
46	500	110	112793.0	12.875913	0.993444	E
565	300	110	262800.0	30.000000	0.977253	E
313	400	110	239107.0	27.295320	0.973326	E
564	300	110	244231.0	27.880251	0.960213	E
45	500	110	97685.4	11.151301	0.960164	E
816	200	110	262800.0	30.000000	0.941316	E
312	400	110	199899.0	22.819521	0.933747	E
1066	100	110	262800.0	30.000000	0.925458	E
815	200	110	244681.0	27.931621	0.925297	E
44	500	110	82577.9	9.426701	0.922672	E
563	300	110	205704.0	23.482192	0.922672	E
1065	100	110	252007.0	28.767922	0.916077	E
311	400	110	173761.0	19.835731	0.903361	E

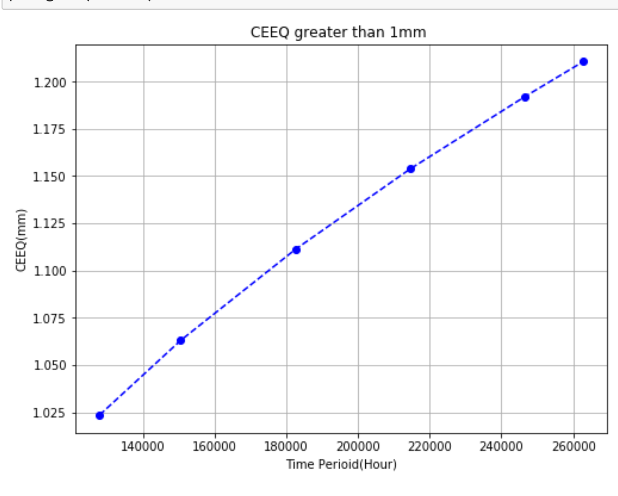
Let's see how many CEEQ has their values greater than 1mm

In [85]:
```
severe_creep=creep[(creep.CEEQ)>1]
print(severe_creep)
```

```
    Temperature  Load  Time Period(Hour)  Time Period(Year)     CEEQ Category
47          500   110           127900.0          14.600457  1.02346        F
48          500   110           150562.0          17.187443  1.06300        F
49          500   110           182565.0          20.840753  1.11116        F
50          500   110           214567.0          24.493950  1.15370        F
51          500   110           246570.0          28.147260  1.19196        F
52          500   110           262800.0          30.000000  1.21042        F
```

So there are six values and let's put them into a graph to see the relation with increasing time period

In [86]:
```
import matplotlib.pyplot as plt
a=severe_creep['Time Period(Hour)']
b=severe_creep['CEEQ']
plt.plot(a,b, color='b', linestyle='--', marker='o')
plt.xlabel('Time Perioid(Hour)')
plt.ylabel('CEEQ(mm)')
plt.title('CEEQ greater than 1mm ')
plt.grid('True')
```



We can filter data by multiple criteria. For example, here we see CEEQ values greater than .8mm at 400 degree Celcius

In [87]:
```
creep[(creep.CEEQ>.8)&(creep.Temperature==400)]
```

Out[87]:

	Temperature	Load	Time Period(Hour)	Time Period(Year)	CEEQ	Category
309	400	110	121484.0	13.868037	0.830312	E
310	400	110	147623.0	16.851941	0.869283	E
311	400	110	173761.0	19.835731	0.903361	E
312	400	110	199899.0	22.819521	0.933747	E
313	400	110	239107.0	27.295320	0.973326	E
314	400	110	262800.0	30.000000	0.995481	E

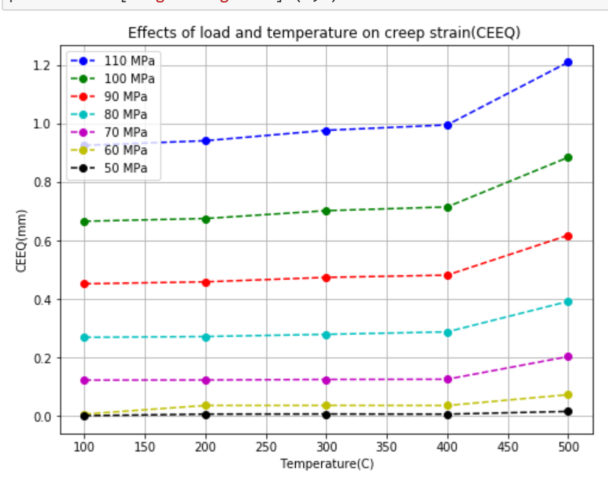
Effects of load and temperature on creep strain

In [88]:
```
d = {'110 MPa' : pd.Series([0.9255,0.9413,0.977,0.9955,1.21], index=['100','200','300','400','500']),
     '100 MPa' : pd.Series([0.6657,0.675,0.7019,0.7146,0.8843],index=['100','200','300','400','500']),
     '90 MPa' : pd.Series([0.4516,0.4582,0.4735,0.4811,0.6176],index=['100','200','300','400','500']),
     '80 MPa' : pd.Series([0.2682,0.271,0.2785,0.2869,0.3912],index=['100','200','300','400','500']),
     '70 MPa' : pd.Series([0.1217,0.1222,0.1241,0.1247,0.2023],index=['100','200','300','400','500']),
     '60 MPa' : pd.Series([0.0054,0.0349,0.035,0.0348,0.0719],index=['100','200','300','400','500']),
     '50 MPa' : pd.Series([1.50E-07,0.0053,0.0057,0.0052,0.0146],index=['100','200','300','400','500'])}
df=pd.DataFrame(d)
df
```

Out[88]:

	110 MPa	100 MPa	90 MPa	80 MPa	70 MPa	60 MPa	50 MPa
100	0.9255	0.6657	0.4516	0.2682	0.1217	0.0054	1.500000e-07
200	0.9413	0.6750	0.4582	0.2710	0.1222	0.0349	5.300000e-03
300	0.9770	0.7019	0.4735	0.2785	0.1241	0.0350	5.700000e-03
400	0.9955	0.7146	0.4811	0.2869	0.1247	0.0348	5.200000e-03
500	1.2100	0.8843	0.6176	0.3912	0.2023	0.0719	1.460000e-02

In [89]:
```
Temperature=[100,200,300,400,500]
b=df['110 MPa']
c=df['100 MPa']
d=df['90 MPa']
e=df['80 MPa']
f=df['70 MPa']
g=df['60 MPa']
h=df['50 MPa']
plt.plot(Temperature,b, color='b', linestyle='--', marker='o',label='110 MPa')
plt.plot(Temperature,c, color='g', linestyle='--', marker='o')
plt.plot(Temperature,d, color='r', linestyle='--', marker='o')
plt.plot(Temperature,e, color='c', linestyle='--', marker='o')
plt.plot(Temperature,f, color='m', linestyle='--', marker='o')
plt.plot(Temperature,g, color='y', linestyle='--', marker='o')
plt.plot(Temperature,h, color='k', linestyle='--', marker='o')
plt.grid('True')
plt.xlabel('Temperature(C)')
plt.ylabel('CEEQ(mm)')
plt.title('Effects of load and temperature on creep strain(CEEQ) ')
plt.legend(loc='upper left')
plt.rcParams['figure.figsize']=(8,6)
```



Cross Validation: Parameter Tuning

Loading the data

In [90]:
```
feature=creep[['Temperature','Load','Time Period(Hour)']]
feature.head()
```

Out[90]:

	Temperature	Load	Time Period(Hour)
0	500	110	0.00
1	500	110	0.05
2	500	110	0.10
3	500	110	0.15
4	500	110	0.20

In [91]:
```
target=creep['Category'].map({'A':0,'B':1,'C':2, 'D':3,'E':4,'F':5})
target.head()
```

Out[91]:
```
0    0
1    0
2    0
3    0
4    0
Name: Category, dtype: int64
```

In [92]:
```
# store feature matrix in "X"
X=feature
# store response vector in "y"
y=target
```

In [93]:
```
feature.dtypes
```

Out[93]:
```
Temperature            int64
Load                   int64
Time Period(Hour)    float64
dtype: object
```

In [94]:
```
target.dtypes
```

Out[94]:
```
dtype('int64')
```

Select the best tuning parameters (aka "hyperparameters") for KNN on the creep dataset

In [95]:
```
from sklearn.model_selection import cross_val_score
from sklearn.neighbors import KNeighborsClassifier
```

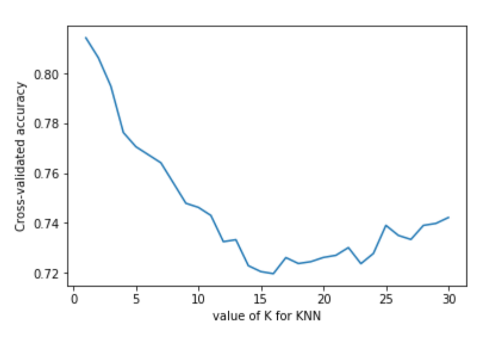
In [96]:
```
k_range=list(range(1,31))
k_scores=[]
for k in k_range:
    knn=KNeighborsClassifier(n_neighbors=k)
    scores=cross_val_score(knn,X,y,cv=10, scoring='accuracy')
    k_scores.append(scores.mean())
print(k_scores)
```

```
[0.8143923822284712, 0.8063742590840283, 0.7949414677182423, 0.7763450459628735, 0.7706576835394561, 0.7674263628576032, 0.7641
996170205049, 0.7560944822149229, 0.7479380038340622, 0.7462851112720787, 0.7430454674536772, 0.7325132360487184, 0.73329356391
75708, 0.7228517207940798, 0.7204781670750715, 0.7196575450694324, 0.7261162619067684, 0.7237301097625632, 0.724482741919826,
0.7261691544687519, 0.7270291207366861, 0.7301384328991121, 0.7236726423558253, 0.7277774776053008, 0.7390629402797351, 0.73501
09975922432, 0.733404223442399, 0.7390503418545382, 0.7398445175791856, 0.7422183708543004]
```

In [97]:
```
import matplotlib.pyplot as plt
%matplotlib inline
```

In [98]:
```
plt.plot(k_range,k_scores)
plt.xlabel('value of K for KNN')
plt.ylabel('Cross-validated accuracy')
```

Out[98]:
```
Text(0, 0.5, 'Cross-validated accuracy')
```



Model selection

Compare the best KNN model with logistic regression on the iris dataset

In [99]:
```
# 10-fold cross-validation with the best KNN model
knn=KNeighborsClassifier(n_neighbors=1)
print(cross_val_score(knn,X,y,cv=10,scoring='accuracy').mean())
```

```
0.8143923822284712
```

In [100]:
```
# 10-fold cross-validation with logistic regression
from sklearn.linear_model import LogisticRegression
logreg=LogisticRegression()
print(cross_val_score(logreg,X,y,cv=10,scoring='accuracy').mean())
```

```
0.7194758698381779
```

Training a machine learning model with scikit-learn

K-nearest neighbors (KNN) classification

In [101]:
```
knn=KNeighborsClassifier(n_neighbors=1)
print(knn)
knn.fit(X,y)
```

```
KNeighborsClassifier(algorithm='auto', leaf_size=30, metric='minkowski',
           metric_params=None, n_jobs=None, n_neighbors=1, p=2,
           weights='uniform')
```

Out[101]:
```
KNeighborsClassifier(algorithm='auto', leaf_size=30, metric='minkowski',
           metric_params=None, n_jobs=None, n_neighbors=1, p=2,
           weights='uniform')
```

Predicting some creep strain values as output of given Temperature(C), Load(MPa) and Time Period(Hour) Comparing the simulated values with the knn predicted values

For temperature 500 degree Celsius and 262800 Hour time period we get 5 values predicted at 5 different Loads and then compare it with known simulated values to see whether our model gives us correct prediction or not

In [102]:
```
print(knn.predict([[500,110,262800]]))
print(knn.predict([[500,100,262800]]))
print(knn.predict([[500,90,262800]]))
print(knn.predict([[500,80,262800]]))
print(knn.predict([[500,70,262800]]))
print(knn.predict([[500,60,262800]]))
print(knn.predict([[500,50,262800]]))
d = {'110 MPa' : pd.Series([1.21,'F',5,5], index=['Simulated CEEQ(mm)','Category','Assinged Values','Predicted knn values']),
     '100 MPa' : pd.Series([.8843,'E',4,4],index=['Simulated CEEQ(mm)','Category','Assinged Values','Predicted knn values']),
     '90 MPa' : pd.Series([.6176,'D',3,3],index=['Simulated CEEQ(mm)','Category','Assinged Values','Predicted knn values']),
     '80 MPa' : pd.Series([.3912,'B',1,1],index=['Simulated CEEQ(mm)','Category','Assinged Values','Predicted knn values']),
     '70 MPa' : pd.Series([.2023,'B',1,1],index=['Simulated CEEQ(mm)','Category','Assinged Values','Predicted knn values']),
     '60 MPa' : pd.Series([.0719,'A',0,0],index=['Simulated CEEQ(mm)','Category','Assinged Values','Predicted knn values']),
     '50 MPa' : pd.Series([.0146,'A',0,0],index=['Simulated CEEQ(mm)','Category','Assinged Values','Predicted knn values'])}
df=pd.DataFrame(d)
df
```

```
[5]
[4]
[3]
[1]
[1]
[0]
[0]
```

Out[102]:

	110 MPa	100 MPa	90 MPa	80 MPa	70 MPa	60 MPa	50 MPa
Simulated CEEQ(mm)	1.21	0.8843	0.6176	0.3912	0.2023	0.0719	0.0146
Category	F	E	D	B	B	A	A
Assinged Values	5	4	3	1	1	0	0
Predicted knn values	5	4	3	1	1	0	0

For temperature 400 degree Celsius and 262800 Hour time period we get 5 values predicted at 5 different Loads and then compare it with known simulated values to see whether our model gives us correct prediction or not

In [103]:
```
print(knn.predict([[400,110,262800]]))
print(knn.predict([[400,100,262800]]))
print(knn.predict([[400,90,262800]]))
print(knn.predict([[400,80,262800]]))
print(knn.predict([[400,70,262800]]))
print(knn.predict([[400,60,262800]]))
print(knn.predict([[400,50,262800]]))
d = {'110 MPa' : pd.Series([.994581,'E',4,4], index=['Simulated CEEQ(mm)','Category','Assinged Values','Predicted knn values']),
     '100 MPa' : pd.Series([0.71458,'D',3,3],index=['Simulated CEEQ(mm)','Category','Assinged Values','Predicted knn values']),
     '90 MPa' : pd.Series([0.481047,'C',2,2],index=['Simulated CEEQ(mm)','Category','Assinged Values','Predicted knn values']),
     '80 MPa' : pd.Series([0.286982,'B',1,1],index=['Simulated CEEQ(mm)','Category','Assinged Values','Predicted knn values']),
     '70 MPa' : pd.Series([0.124644,'A',0,0],index=['Simulated CEEQ(mm)','Category','Assinged Values','Predicted knn values']),
     '60 MPa' : pd.Series([0.0348307,'A',0,0],index=['Simulated CEEQ(mm)','Category','Assinged Values','Predicted knn values']),
     '50 MPa' : pd.Series([0.00522387,'A',0,0],index=['Simulated CEEQ(mm)','Category','Assinged Values','Predicted knn value
s'])}
df=pd.DataFrame(d)
df
```

```
[4]
[3]
[2]
[1]
[0]
[0]
[0]
```

Out[103]:

	110 MPa	100 MPa	90 MPa	80 MPa	70 MPa	60 MPa	50 MPa
Simulated CEEQ(mm)	0.994581	0.71458	0.481047	0.286982	0.124644	0.0348307	0.00522387
Category	E	D	C	B	A	A	A
Assinged Values	4	3	2	1	0	0	0
Predicted knn values	4	3	2	1	0	0	0