



# Mo İlavesinin ve Proses Parametrelerinin Östemperlenmiş Sünek Dökme Demirlerin Mekanik Özelliklerine Etkisi

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# Sunum İeriđi

- ❖ Kısaca Firma Tanıtımı
- ❖ Östemperlenmiş Sünek Dökme Demirler (ADI)
- ❖ Deneysel alıřmalar
- ❖ Sonular ve Tartıřma



# MOTUS OTOMOTİV

- Markalarımız



# MOTUS OTOMOTİV

- 2003 yılında Konya'da kurulan Motus Otomotiv, binek ve ticari araç motorlarına yönelik her türlü krank milleri, iş makinelerine ait kazıcı ve koruyucu parçalar, kar bıçakları,

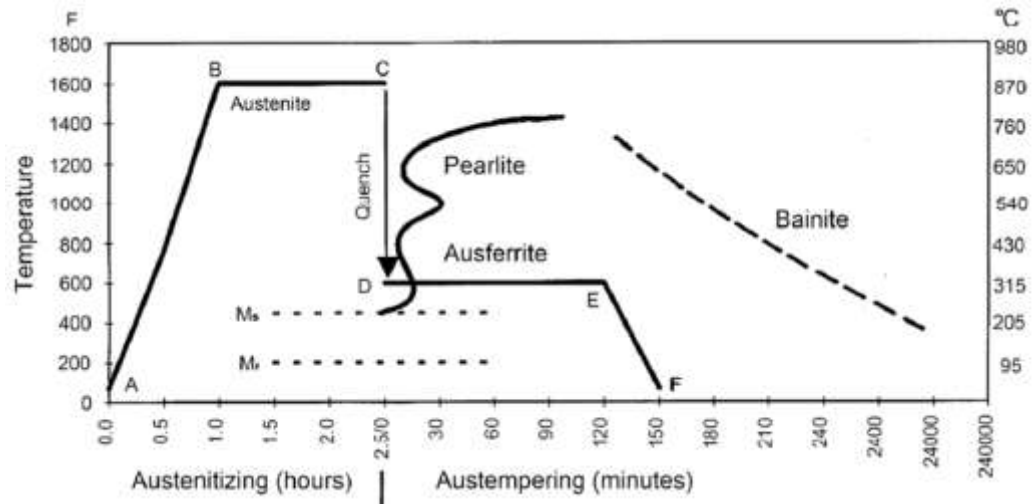
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yardımcı m

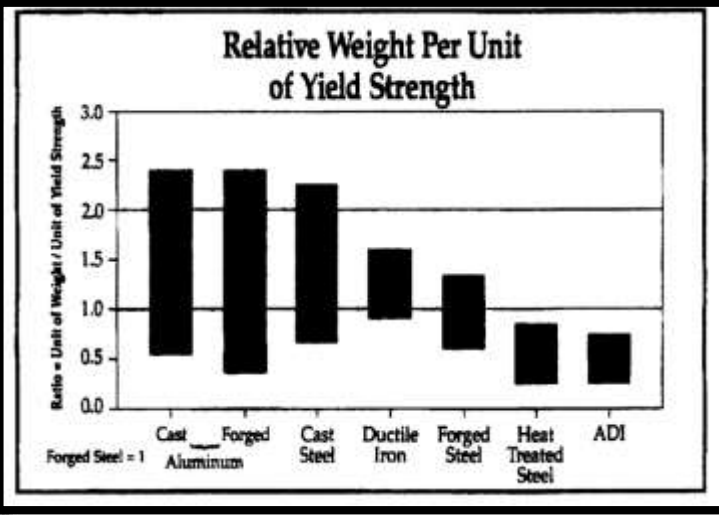
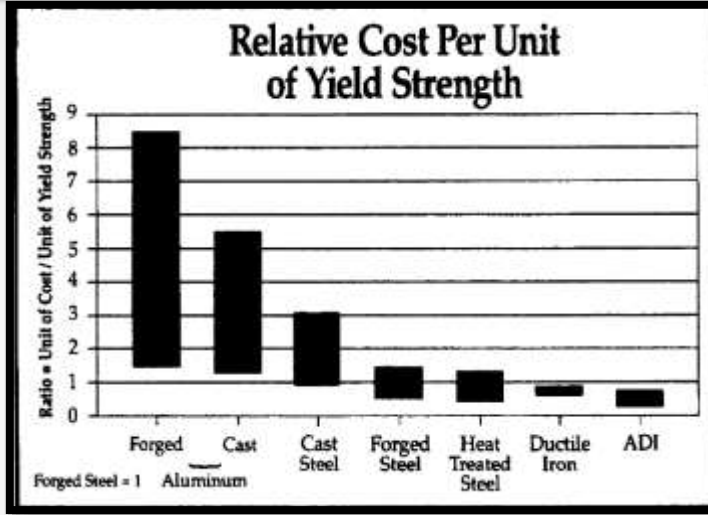


- Küresel grafitli dökme demirlerin mekanik ve fiziksel özellikleri **östemperleme** adı verilen ısı işlemi ile önemli ölçüde artmaktadır.

- **Östemperlenmiş sünek dökme demirlerin üstün özellikleri:**

- Yüksek Dayanım
- İyi Süneklik
- Yüksek Tokluk
- Yüksek Aşınma Direnci
- Yüksek Yorulma Direnci





**Dövme çeliklerin** yerine ADI kullanılarak **ağırlığında % 10 azalma** gerçekleştirilebilir.

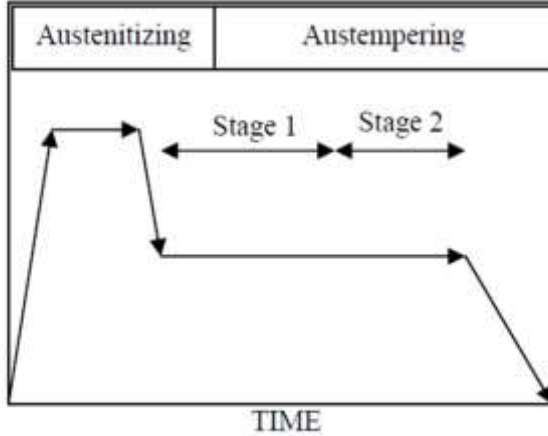
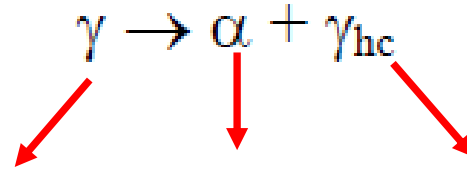


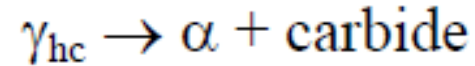
Figure1. Schematic diagram of the austempering heat-treatment process<sup>(2)</sup>

Östempereleme sırasında 2 basamaklı dönüşüm gerçekleşir.

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## ETKİ EDEN FAKTÖRLER

- Nodülarite: % 80 'den fazla olmalıdır.
- Nodül sayısı: minimum 100/mm<sup>2</sup> olmalıdır.
- Kimyasal bileşim parça boyunca aynı olmalıdır.
- Karbür, porozite, inklüzyon bulunmamalıdır.
- Uygun perlit/ferrit oranına sahip olmalıdır.



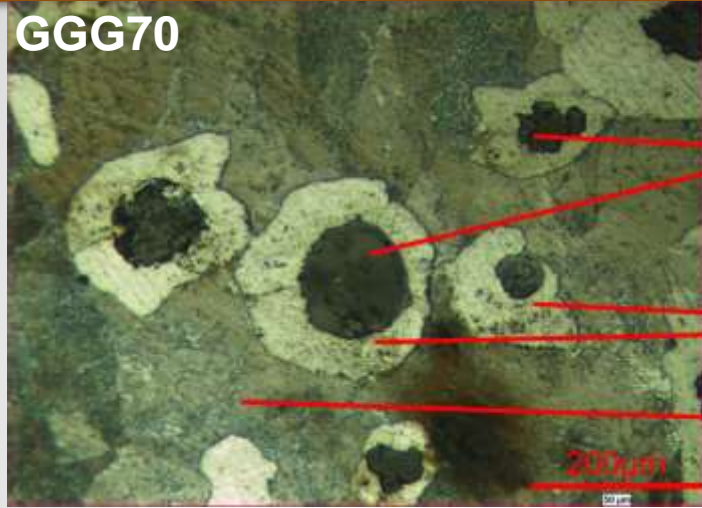
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• \*\*\*\*KARBON EŞDEĞERİ:

-



GGG70

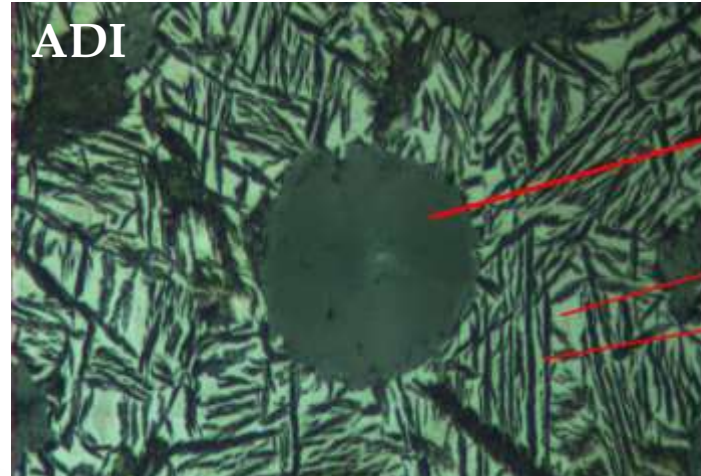


Graphite

Ferrite

Pearlite

ADI



Graphite

Austenite

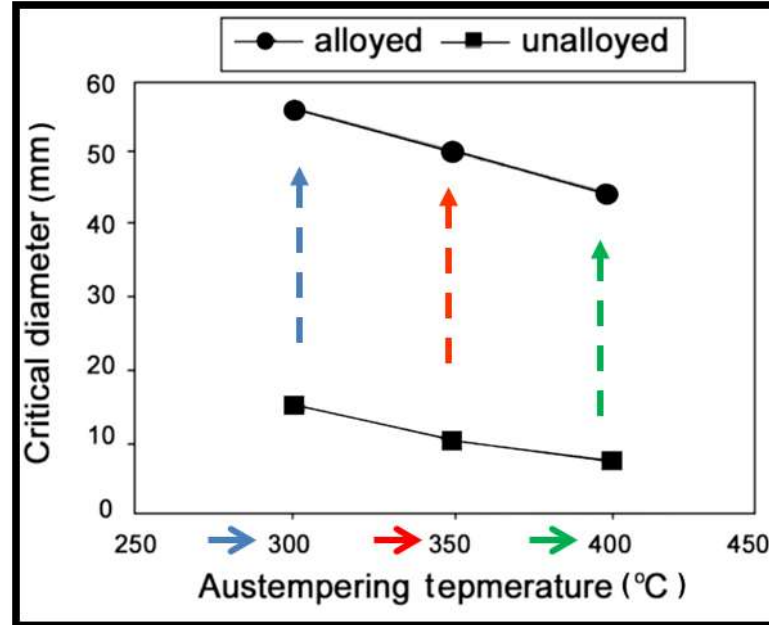
Aussferrite

# Kritik Östempirlenebilirlik Çapı

- ❖  $D_c$  = Kritik östempirlenebilirlik çapı (mm)
- ❖  $D_c(\text{mm}) = 124C_y + 27(\% \text{ Si}) + 25(\% \text{ Mo}) + 22(\% \text{ Mn}) + 16(\% \text{ Ni}) - 1.68 \cdot 10^{-4} T_A^2 + 62(\% \text{ Cu} \% \text{ Mo}) + 12(\% \text{ Cu} \% \text{ Ni}) + 11(\% \text{ Mn} \% \text{ Cu}) + 88(\% \text{ Ni} \% \text{ Mo}) - 20(\% \text{ Mn} \% \text{ Ni}) + 127(\% \text{ Mn} \% \text{ Mo}) - 137$

- ❖  $T_\gamma = 900^\circ\text{C}$  (östenitleme sıcaklığı)
- ❖  $t = 120$  dakika (östenitleme süresi)
- ❖ Kompozisyon: Fe-3.14C-2.67Si-0.3Cu-0.8Ni-0.25Mo-0.07Mn-0.12C

Bosnjak B, Rudoljic B, Tonev K P, et al. Microstructural and mechanical characteristics of low alloyed Ni-Mo-Cu austempered ductile iron. ISIJ International, 2000, 40(12): 1246 –1252.



# Çalışmanın Amacı

*Bu çalışmada,*

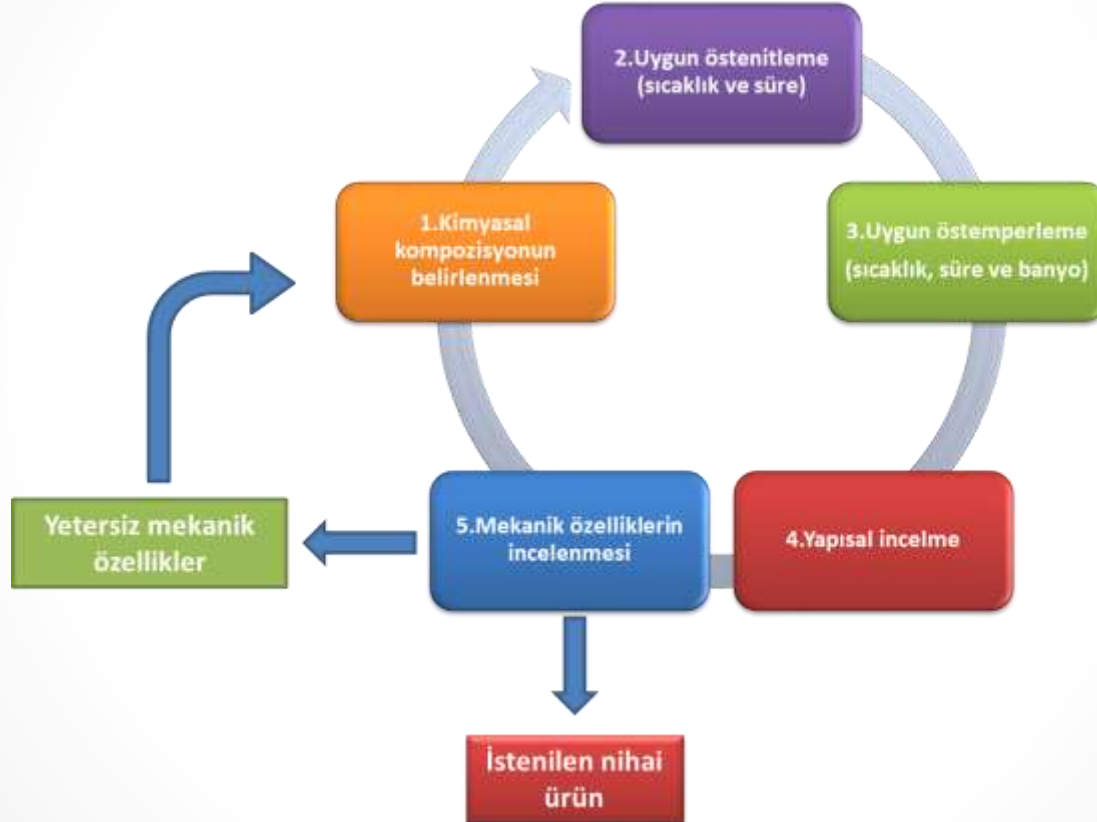
➤ *Mo (Mo+Ni) ilavesinin ve*

*GGG-70 (EN-GJS-700 -2)*

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- 
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# Çalışma Akış Şeması



# Deneysel Çalışma

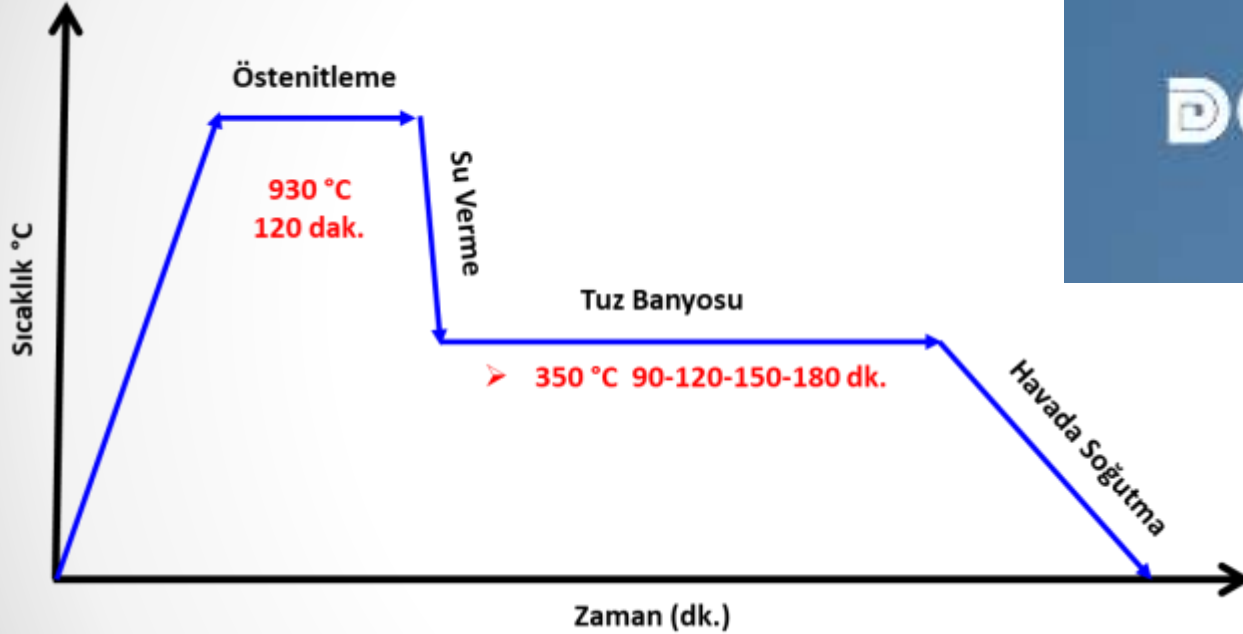
## 1. Üretim

Bileşim	Fe	C	Si	Mn	Cu	Mg	Ni	Mo	Ceq.
% 0 Mo	bal.	3,56	2,24	0,108	0,841	0,036	0,004	<0.001	<b>4,32</b>
% 0,2 Mo	bal.	3,49	2,40	0,083	0,824	0,050	0,001	0,197	<b>4,31</b>
% 0,2 Mo + 0,6 Ni	bal.	3,56	2,33	0,086	0,826	0,033	0,599	0,191	<b>4,35</b>



# Deneysel Çalışma

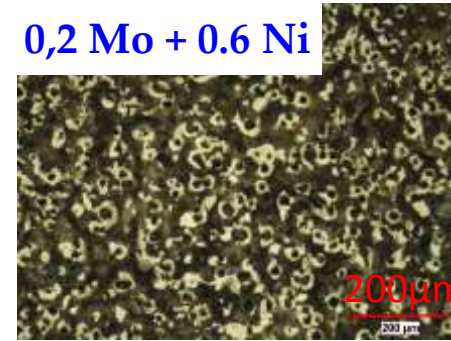
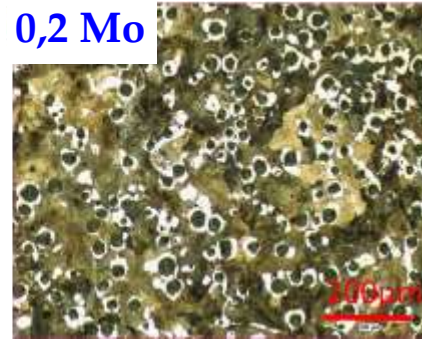
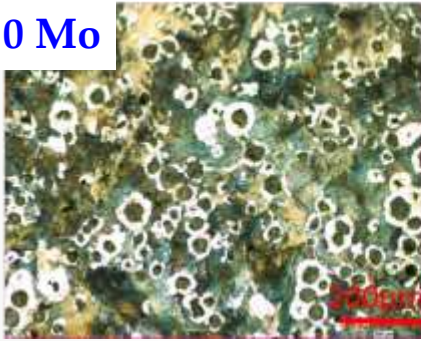
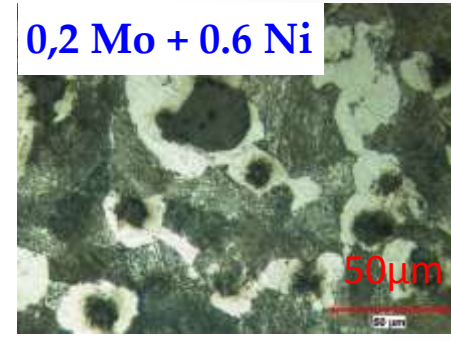
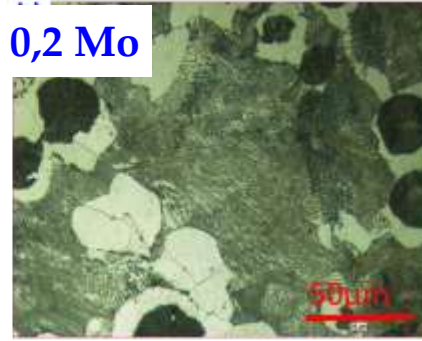
## 2. Isıl İşlem



**DÖKSAN**  
Isıl İşlem

# ÇEKME ÇUBUKLARI

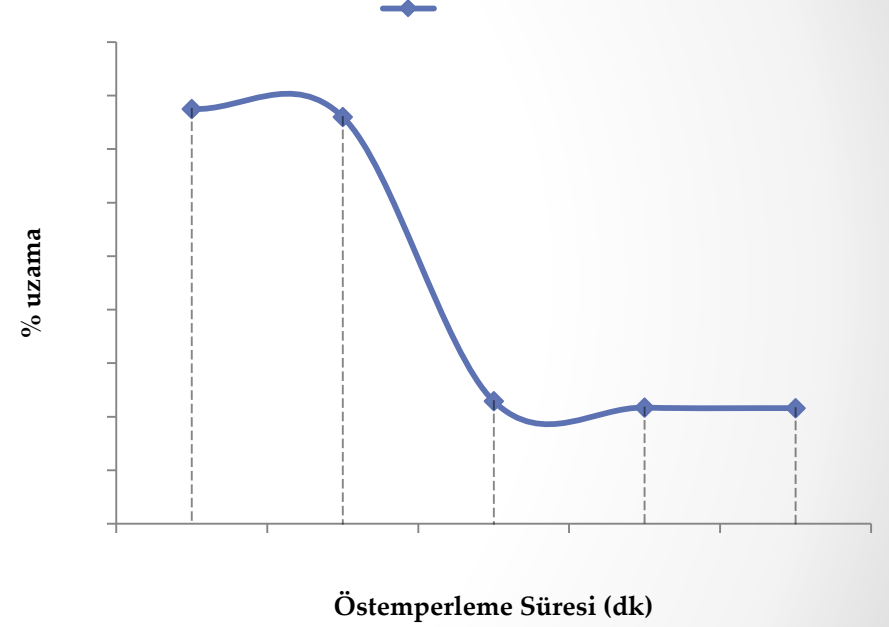
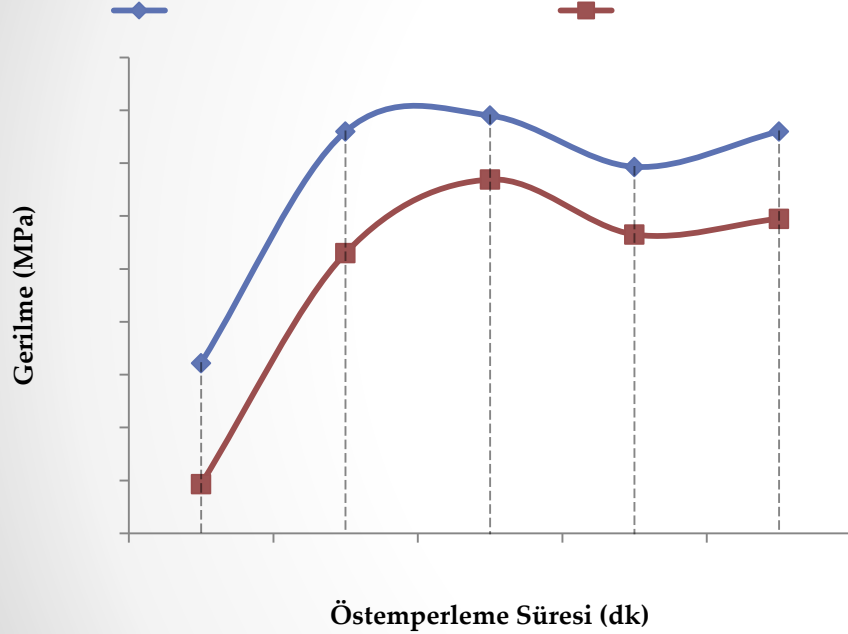
# Dökülmüş haldeki Çekme Çubuğu Mikroyapı ve Mekanik Özellikler



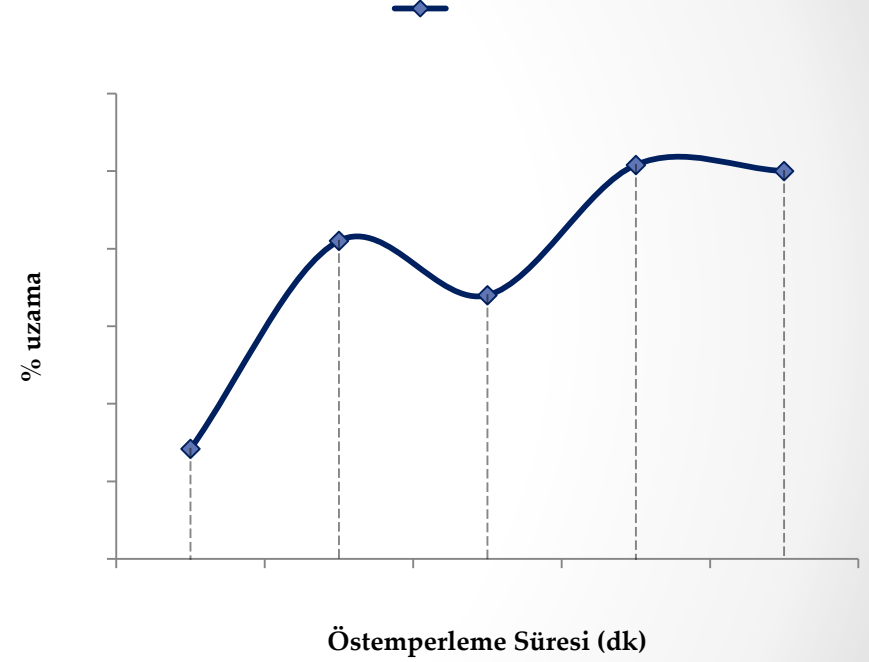
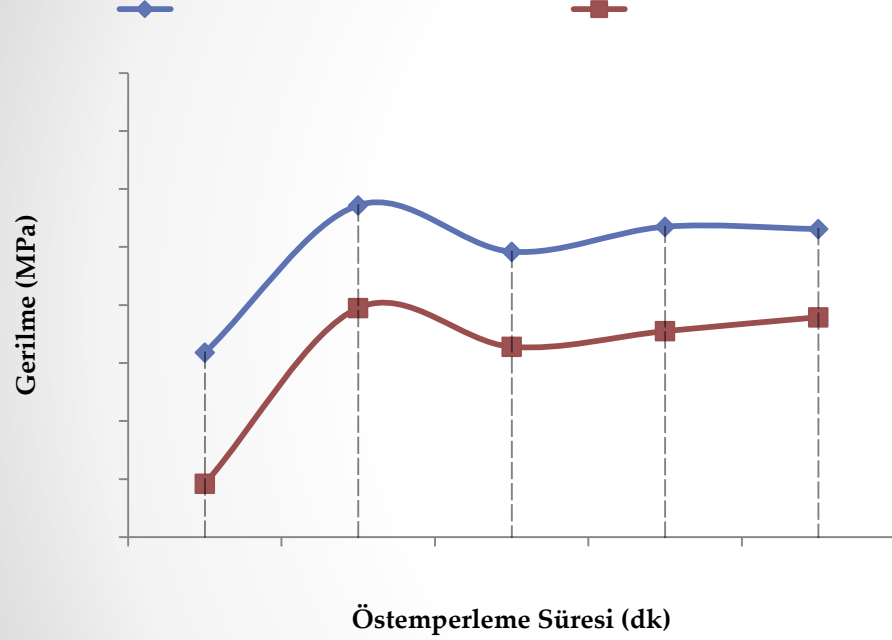
Bileşim	Sertlik	Çekme Dayanımı (MPa)	Akma Dayanımı (MPa)	Uzama (%)
% 0 Mo	203	722	493	5,80
% 0,2 Mo	207	720	492	5,71
% 0,2 Mo + 0,6 Ni	229	715	491	5,80



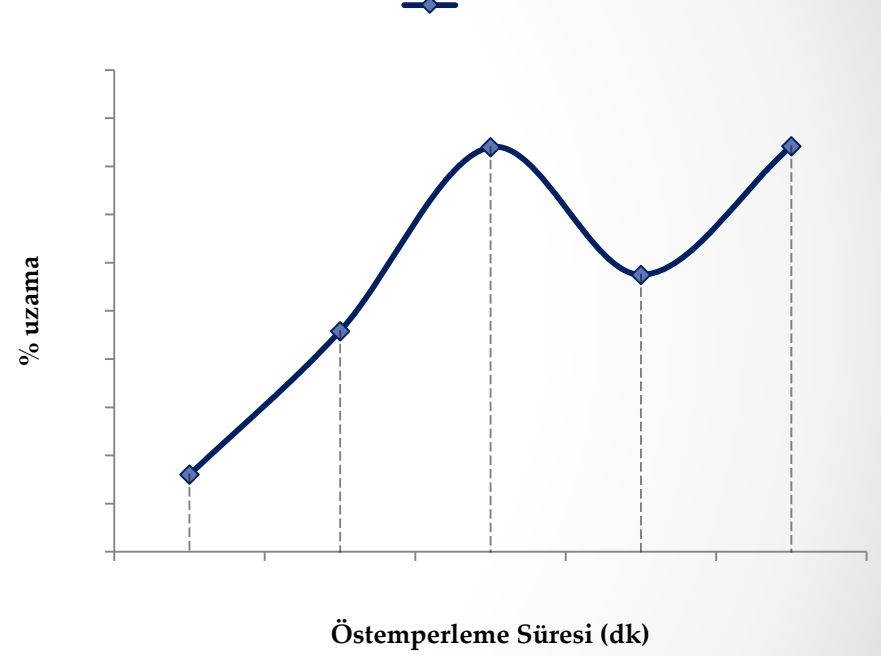
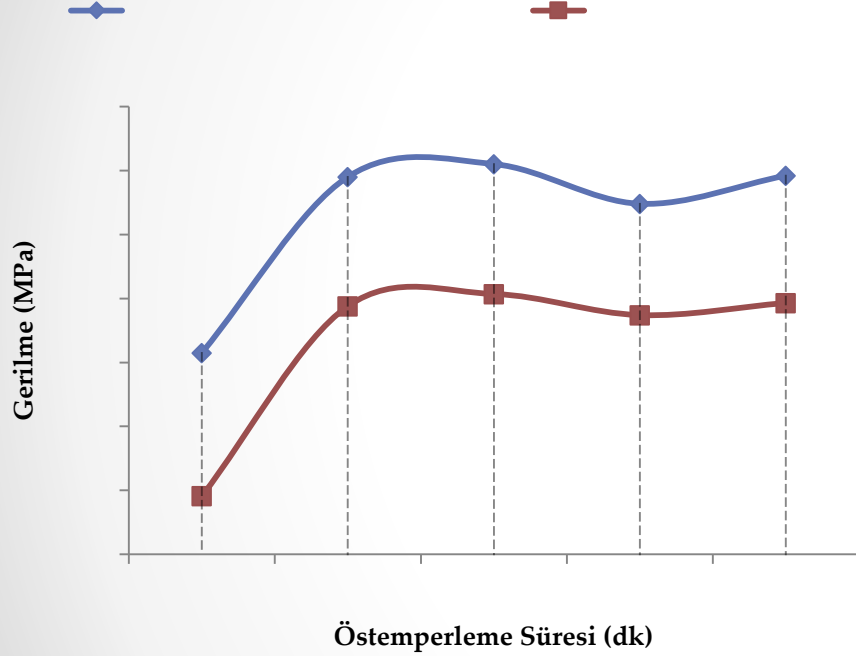
# Alaşımsız % 0 Mo

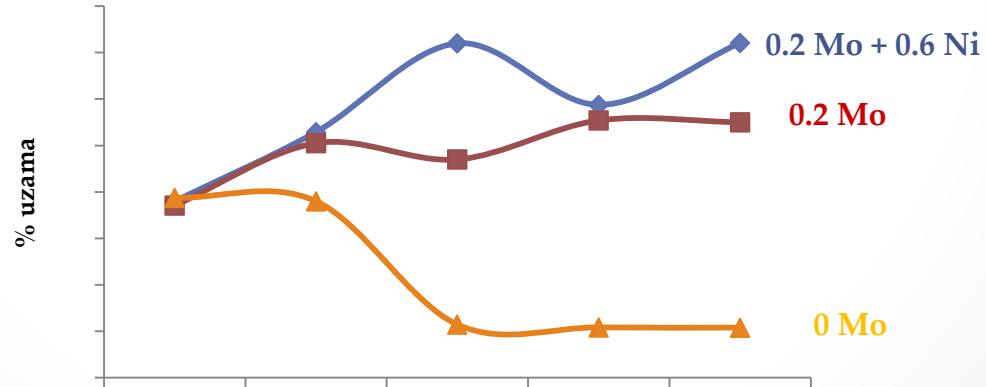
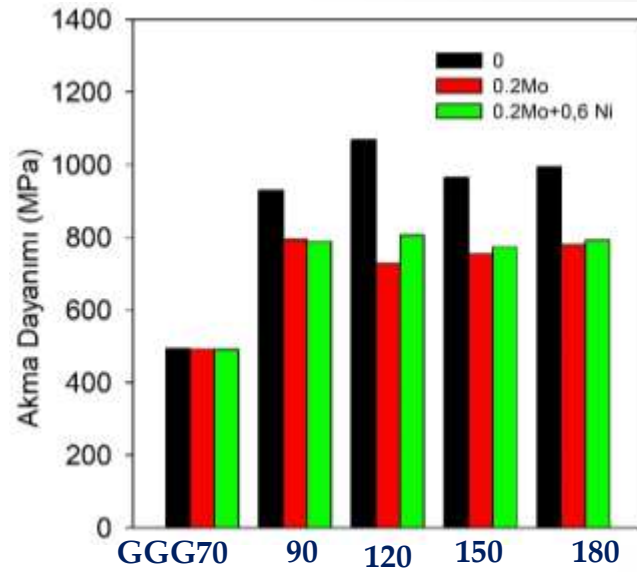
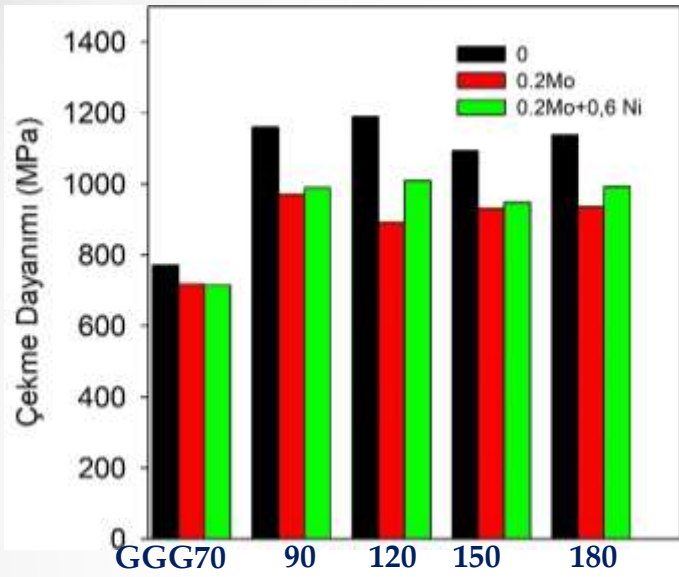


# % 0.2 Mo

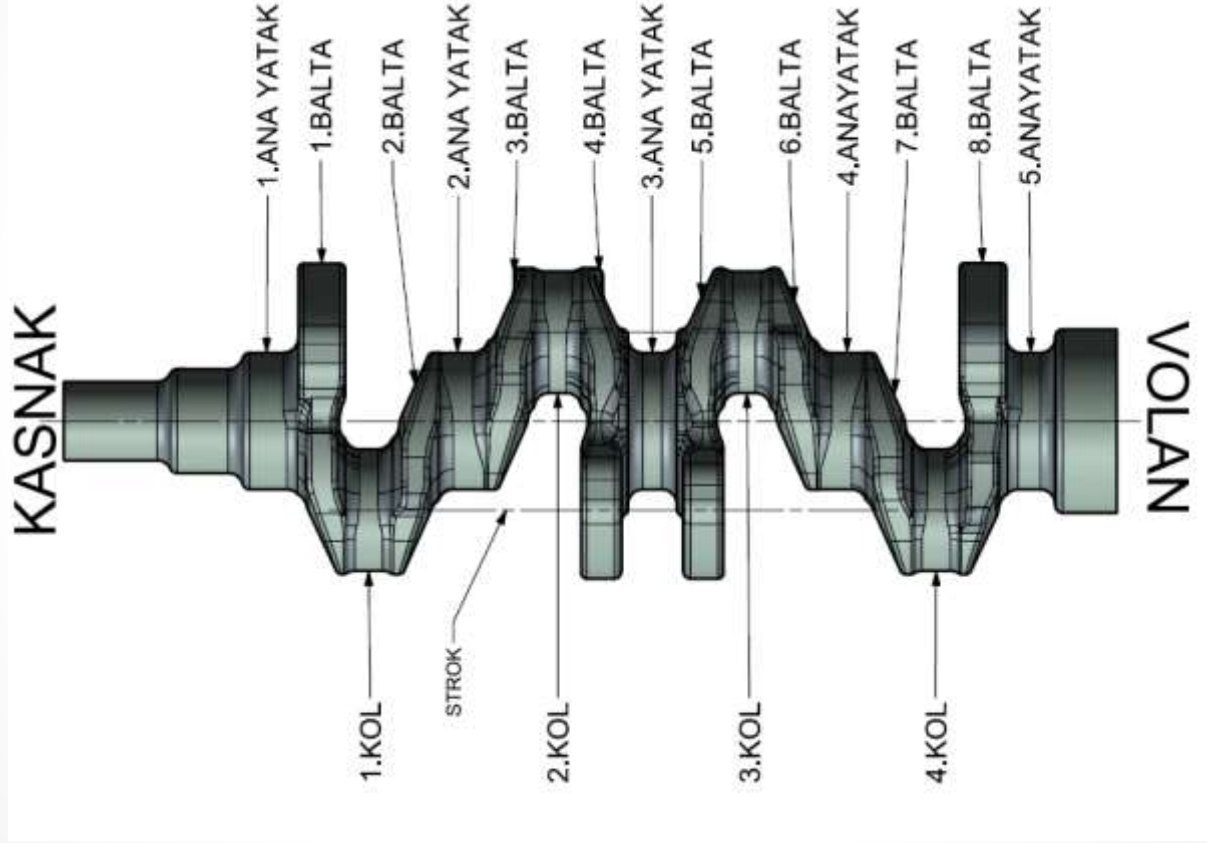


# % 0.2 Mo + 0.6Ni





# KRANK MİLLERİ



350 °C 90 dakika

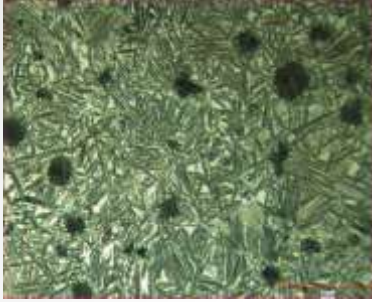
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Kol (orta kesit)

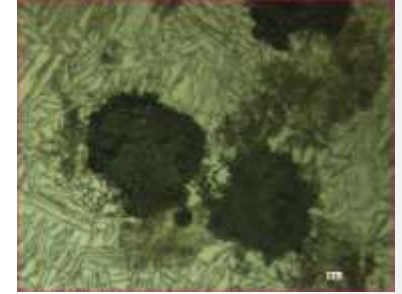
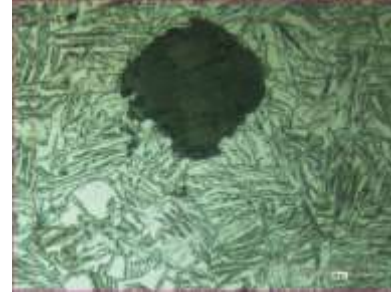
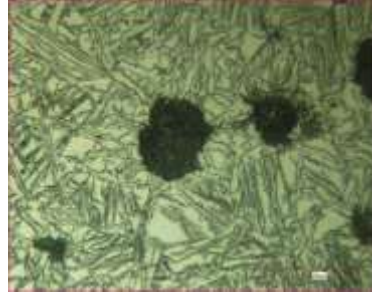
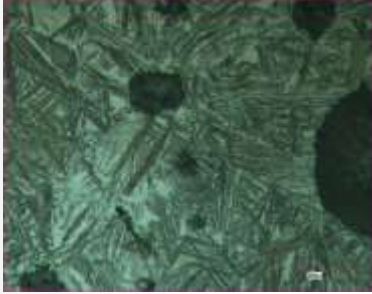
Ana Yatak Yüzey

Ana Yatak Merkez

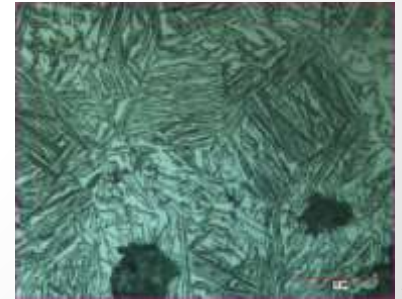
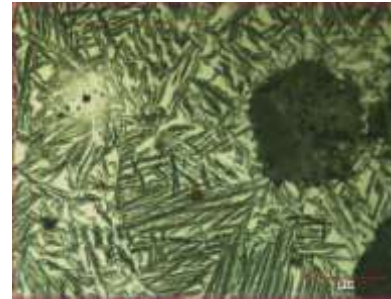
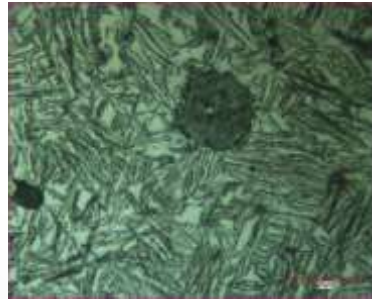
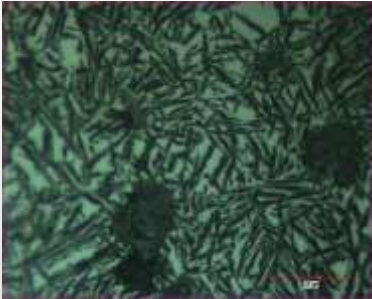
% 0 Mo



% 0.2 Mo



% 0.2 Mo +0.6 Ni



350 °C 120 dakika

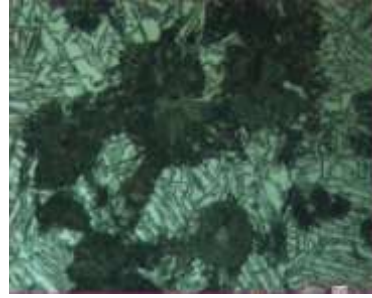
Balta (ince kesit)

Kol (orta kesit)

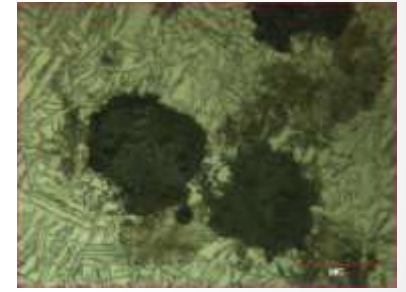
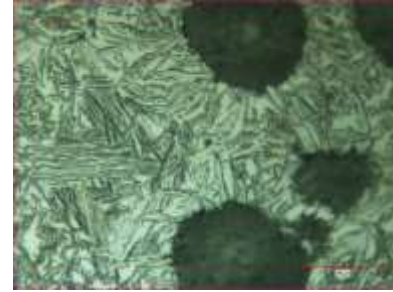
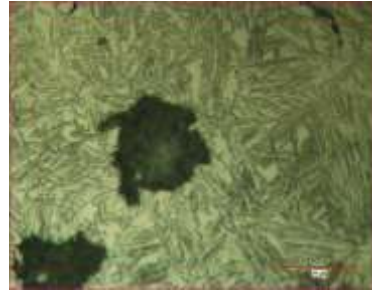
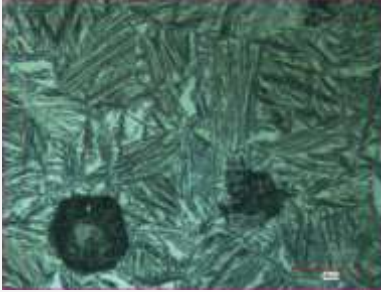
Ana Yatak Yüzey

Ana Yatak Merkez

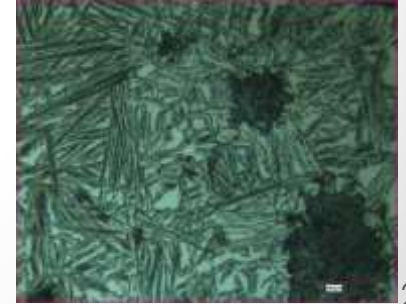
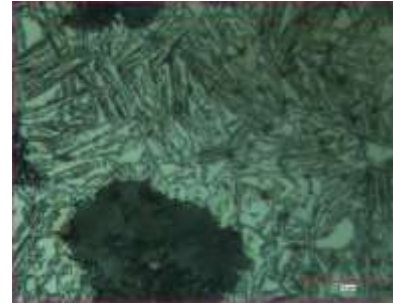
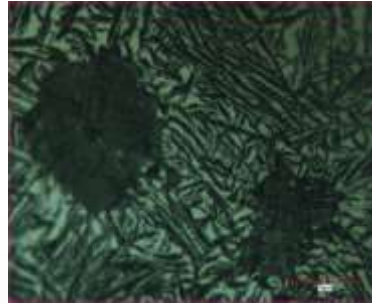
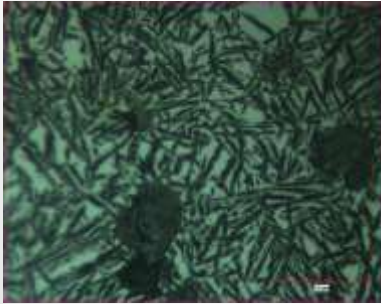
% 0 Mo



% 0.2 Mo



% 0.2 Mo +0.6 Ni



350 °C 150 dakika

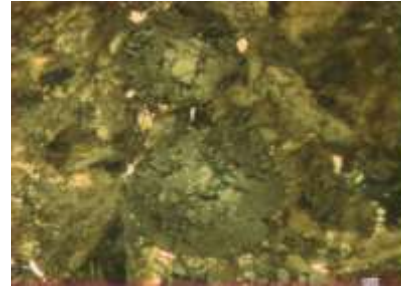
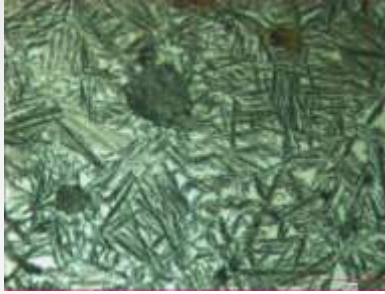
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Kol (orta kesit)

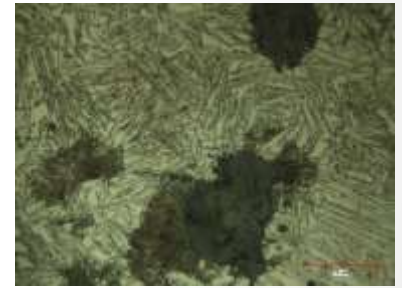
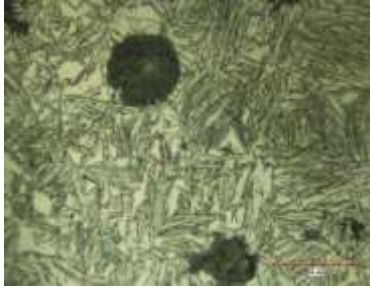
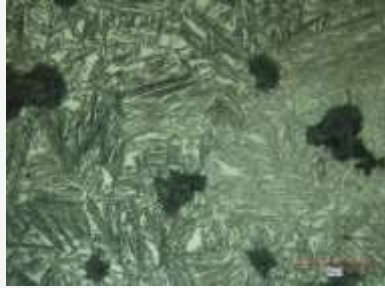
Ana Yatak Yüzey

Ana Yatak Merkez

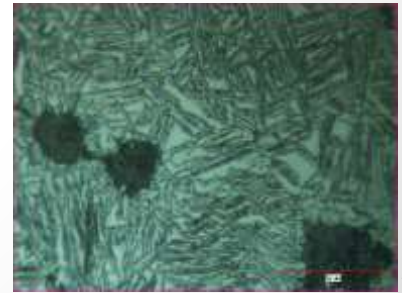
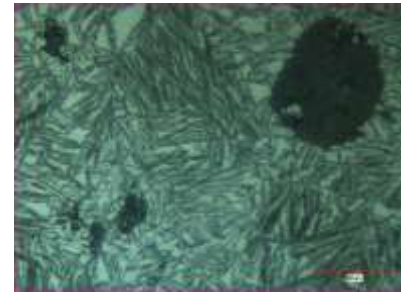
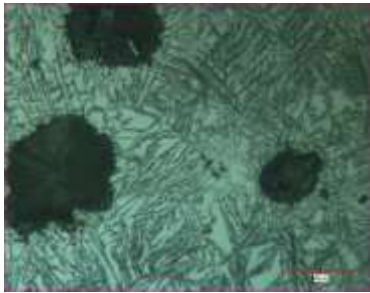
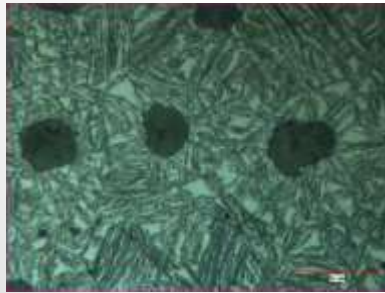
% 0 Mo



% 0.2 Mo



% 0.2 Mo +0.6 Ni





% 0.2 Mo +0.6 Ni

% 0 Mo

Süre	Balta	Kol	Ana Yatak Yüzey	Ana Yatak Merkez
90 dak.	331	321	304	308
120 dak.	316	323	321	323
150 dak.	297	320	326	318
180 dak.	321	318	325	330
90 dak.	260	306	301	301
120 dak.	280	307	307	299
150 dak.	298	309	299	306
180 dak.	281	306	309	300

# Sonuçlar

% 0 Mo  $\longrightarrow$  % 0.2 Mo  $\longrightarrow$  % 0.2 Mo + 0.6 Ni

- Östemperlenme kabiliyeti artmaktadır.
- Uzama değerleri artmaktadır.

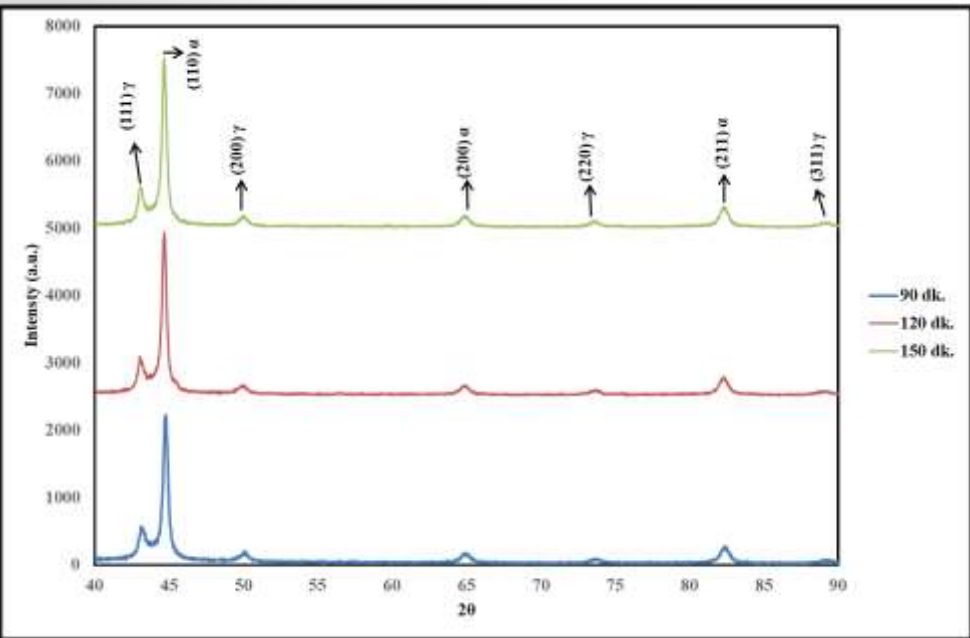
## Çekme Çubuğu

- *En düşük uzama ve en yüksek dayanım:* Alaşım~~sız~~ % 0 Mo

## Krank Mili

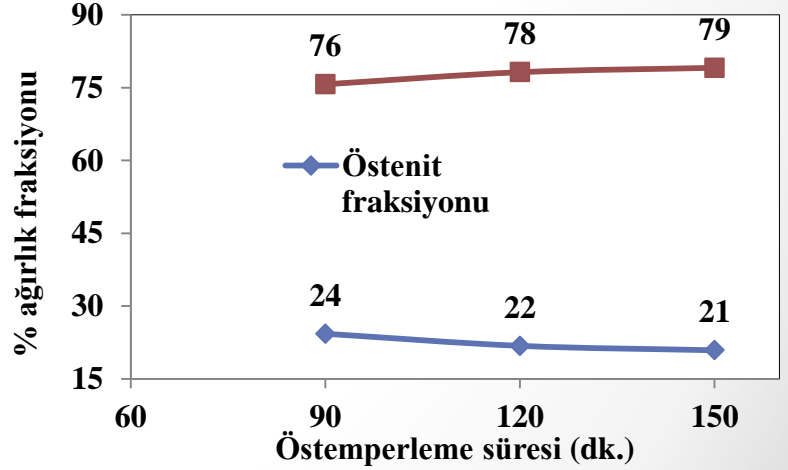
- *En iyi özellikler:* % 0.2 Mo + 0.6 Ni

$$\triangleright a_v = 3.548 + 0.044C_v$$



3,63	1,97
3,64	2,10
3,64	2,12

### Faz fraksiyonları



# TEŐEKKÖR



**DÖKSAN**  
ııl iőlem

# TEŞEKKÜR



## TÜBİTAK

7180889 numaralı

*“Östemperlenmiş sünek dökme demir krank millerinin üretimi  
ve mekanik özelliklerinin belirlenmesi”*

isimli TÜBİTAK 1507 projesi



**MOTUS**<sup>RS</sup>

## Teşekkürler...



# Referanslar

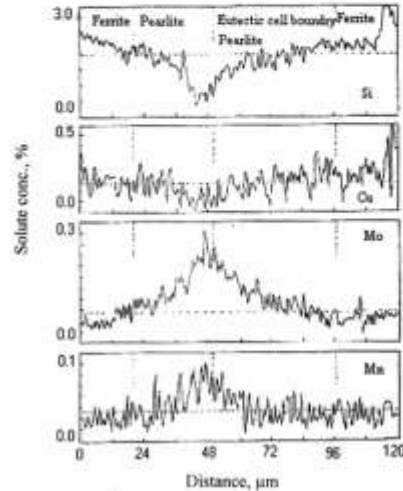
1. Automotive Applications of Austempered Ductile Iron (ADI): A Critical Review  
John R. Keough and Kathy L. Hayrynen Applied Process
2. Bosnjak B, Rudolovic B, Tonev K P, et al. Microstructural and mechanical characteristics of low alloyed Ni-Mo-Cu austempered ductile iron. ISIJ International, 2000, 40(12): 1246 –1252.
3. Yazdani S and Elliott R. Influence of Molybdenum on austempering behaviour of ductile iron – part 4. Materials Science and Technology, August 1999, Vol. 15(5): 896–902.



MOTUS

# elementlerinin etkisi

Element	Uygun aralık (% ağı.)



Si

Cu

Mo

Mn

Mo içeriği (% ağı.)	Hücreler arası karbür hacmi (%)

Mo içeriğine göre ADI için hücreler arası karbürlerin miktarı

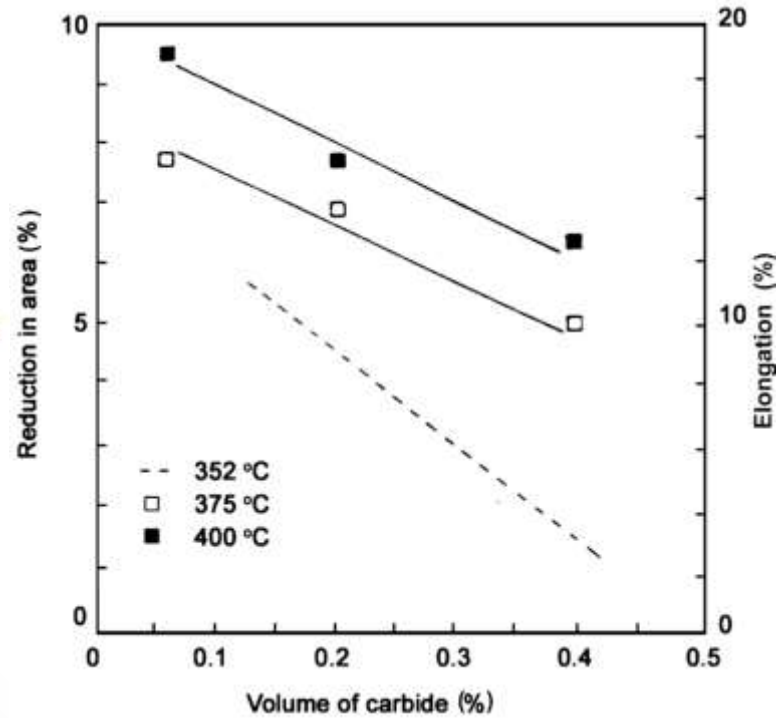


Alaşım elementlerinin kullanılabilirlik aralığı

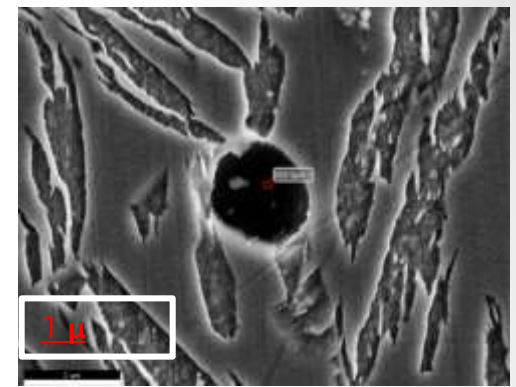
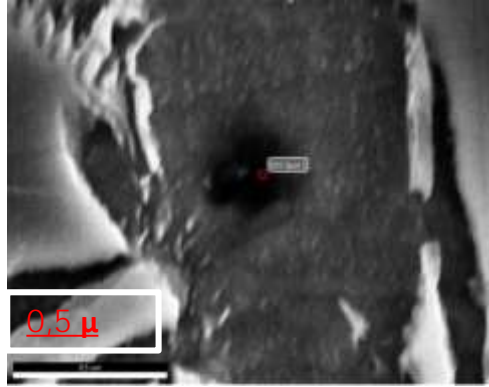
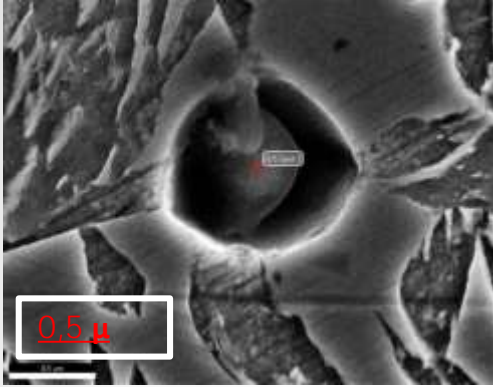




# daralmasının varyasyonları



# SEM-EDX Analizi-0,6Ni-0,2Mo 120 dk



Element	% ağırlıkça
<b>Mo</b>	<b>41,36</b>
<b>Mn</b>	<b>15,91</b>

Element	% ağırlıkça
<b>Mo</b>	<b>57,45</b>
<b>Mn</b>	<b>19</b>

Element	% ağırlıkça
<b>Mo</b>	<b>14,53</b>
<b>Mn</b>	<b>43,19</b>