



**STUDIO DELLA RISPOSTA STRUTTURALE
DEL TELAIO E DEL FORCELLONE POSTERIORE
DI UN MOTOCICLO DUCATI IN CONDIZIONI
DI MARCIA SU STRADA**

**Candidato:
Giacomo PERNA**

**Relatore:
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**Correlatore:
Chiar.mo prof. Ing. Luca PIANCASTELLI
Ing. Stefano CASSANI**

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- **RILIEVI SPERIMENTALI SU MOTOCICLO STRUMENTATO IN CONDIZIONI DI MARCIA SU STRADA**
 - **INDIVIDUAZIONE DI TUTTI I CARICHI TRAMITE MODELLO MULTY-BODY MSC ADAMS**
 - **VERIFICHE DI RESISTENZA TRAMITE ANALISI FEM**
 - **INDIVIDUAZIONE DEI MODI DI VIBRARE**

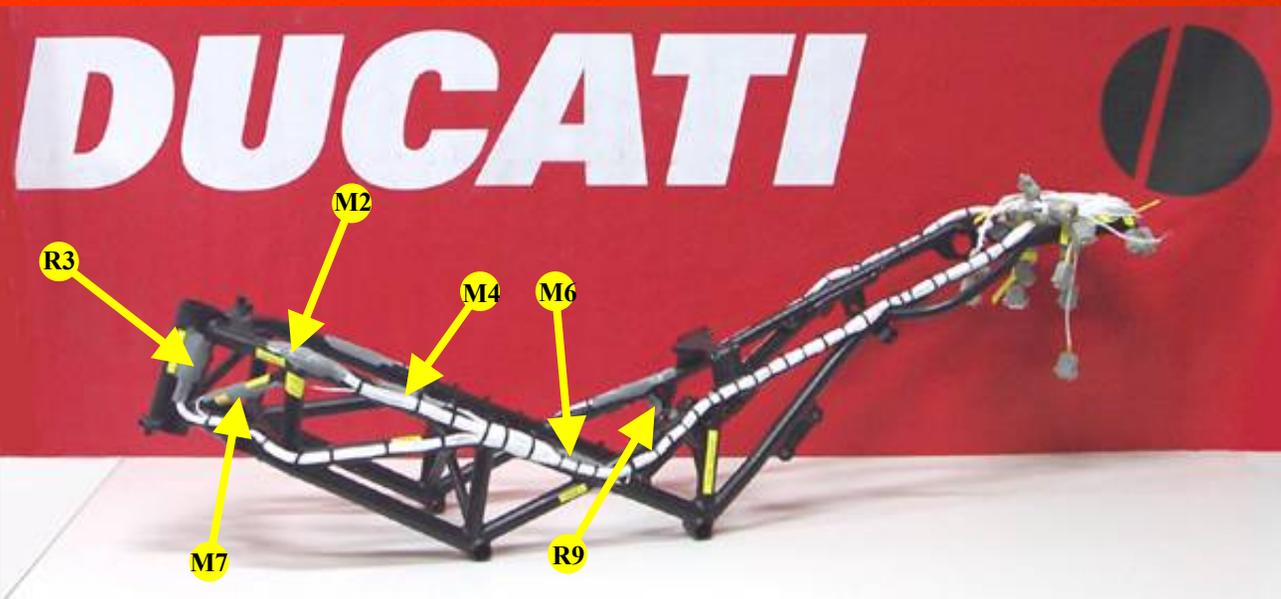


STRUMENTAZIONE DEL **TELAIO
DELLA **FORCELLA ANTERIORE**
E DEL **FORCELLONE POSTERIORE**
CON ESTENSIMETRI**



PROCEDURA DI MONTAGGIO DEGLI ESTENSIMETRI

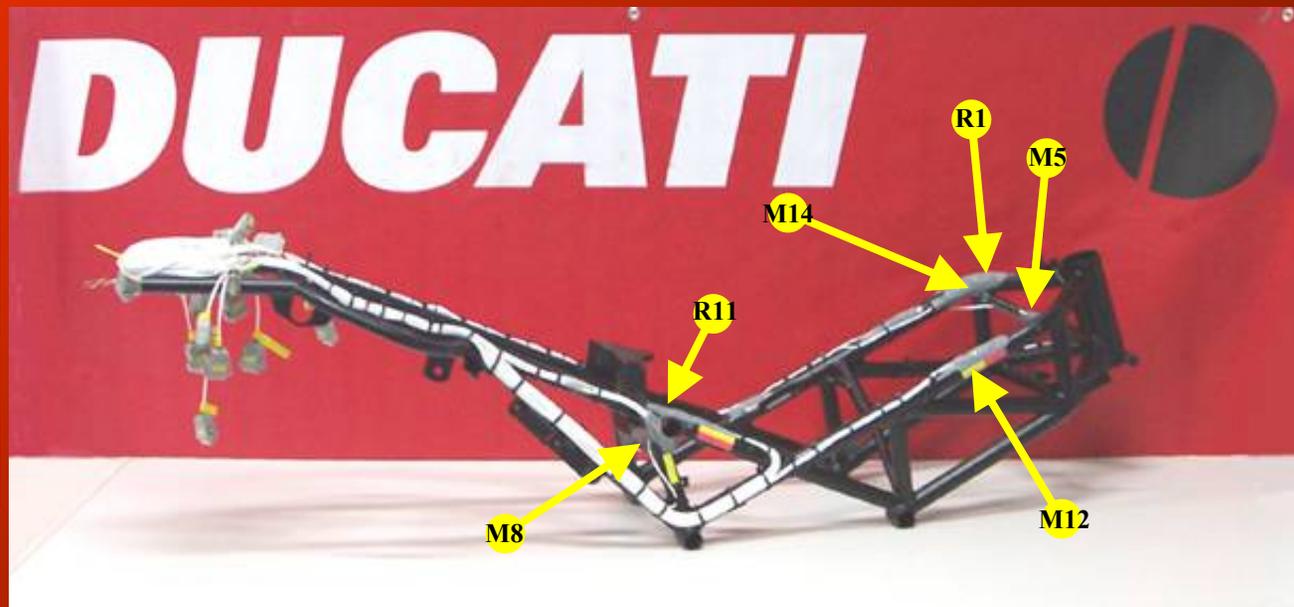
- **PREPARAZIONE DELLA SUPERFICIE**
- **INCOLLAGGIO DELL'ESTENSIMETRO**
- **PREPARAZIONE DEL CABLAGGIO**
- **L'APPLICAZIONE DELLE PROTEZIONI**

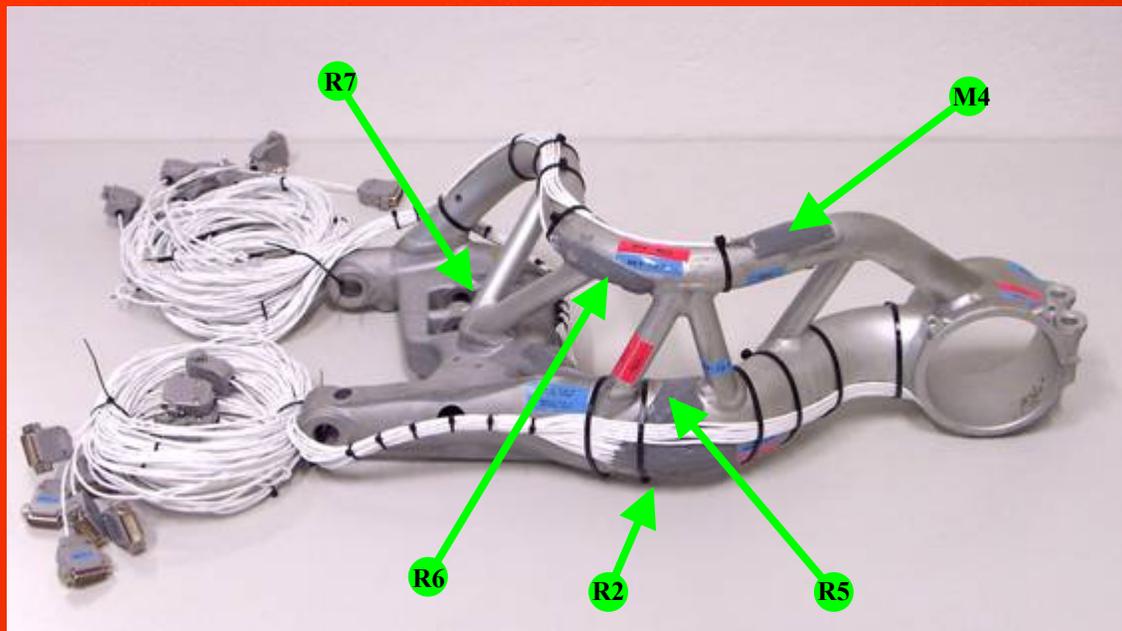


M = Estensimetro
monodirezionale

R = Rosetta

PUNTI SCELTI PREVIA
ANALISI FEM

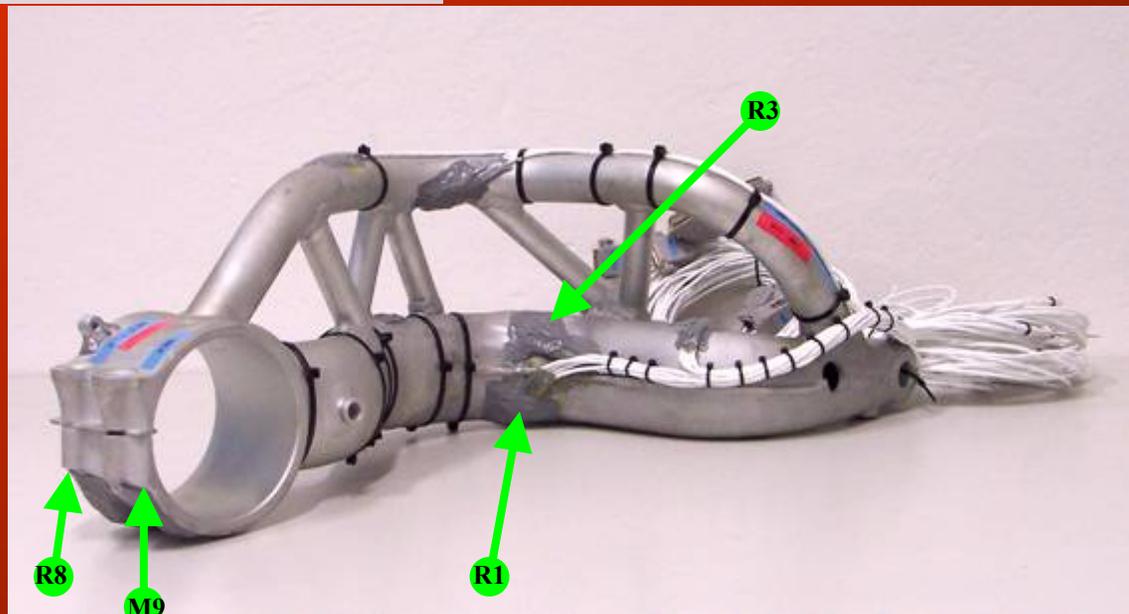


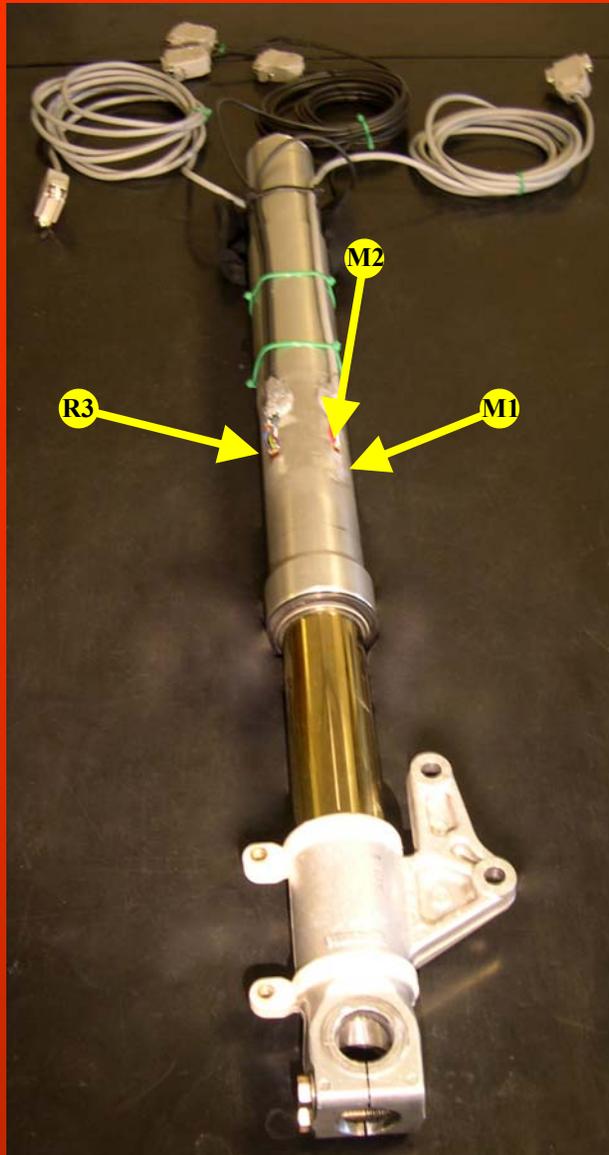


M = Estensimetro
monodirezionale

R = Rosetta

PUNTI SCELTI PREVIA
ANALISI FEM

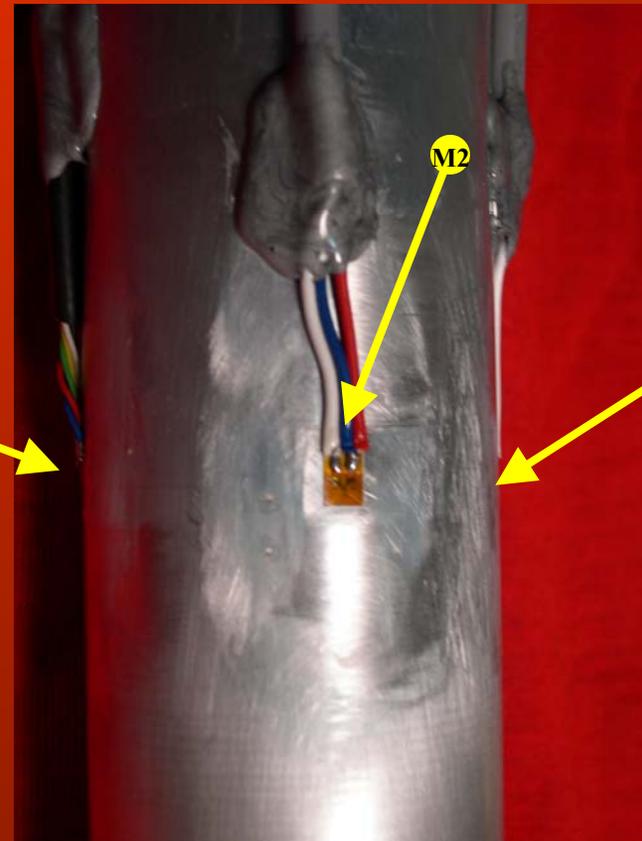


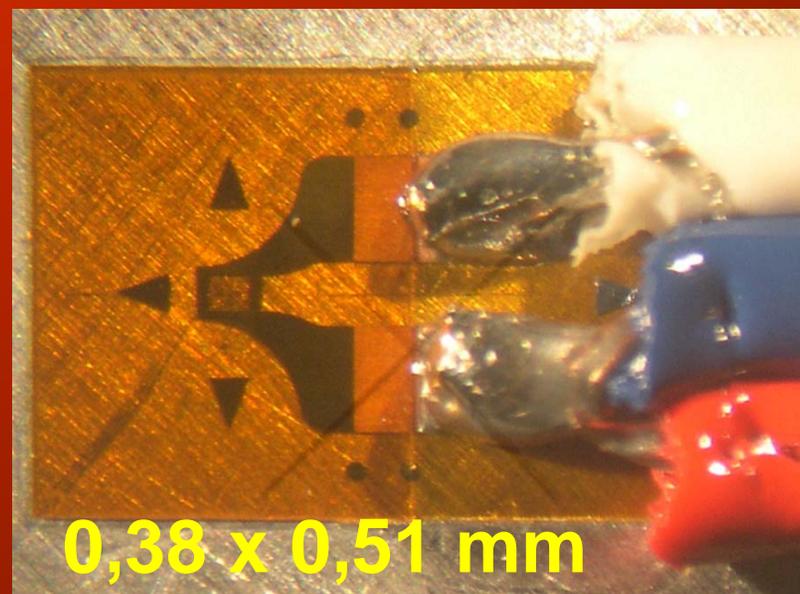
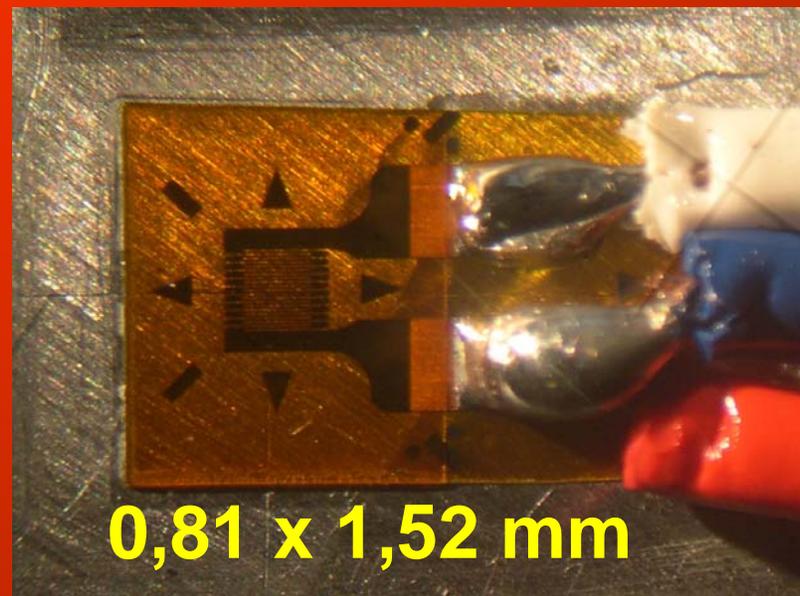
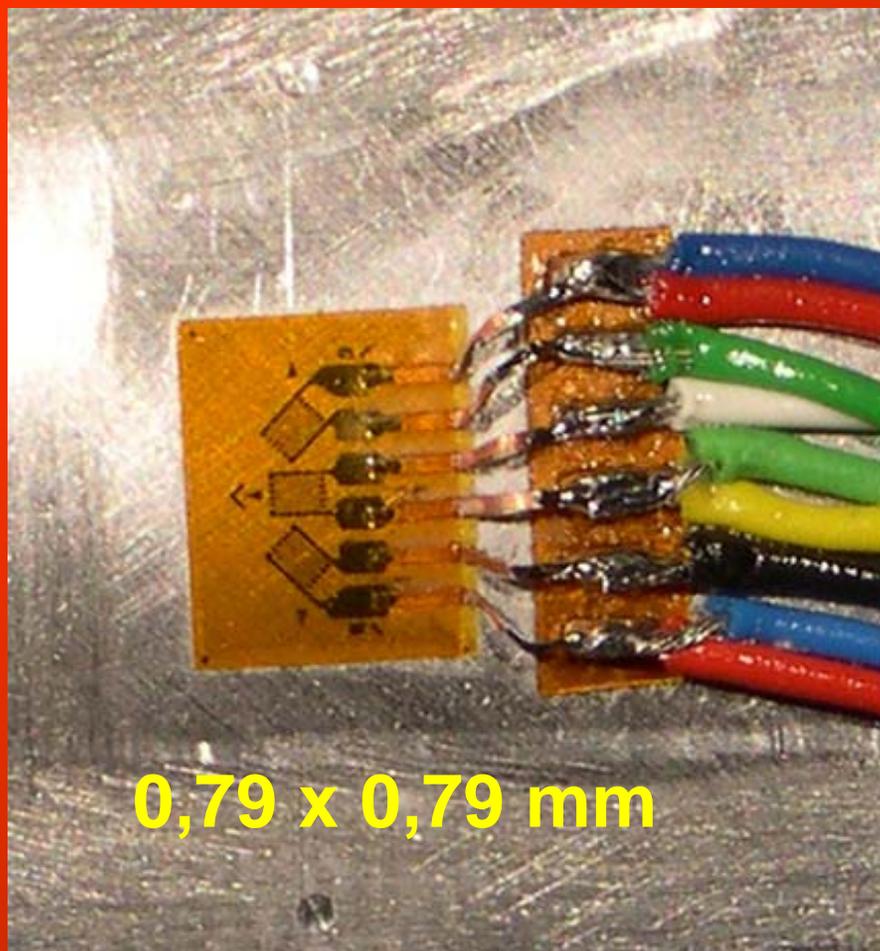


M = Estensimetro
monodirezionale

R = Rosetta

PUNTI SCELTI PREVIA
ANALISI FEM

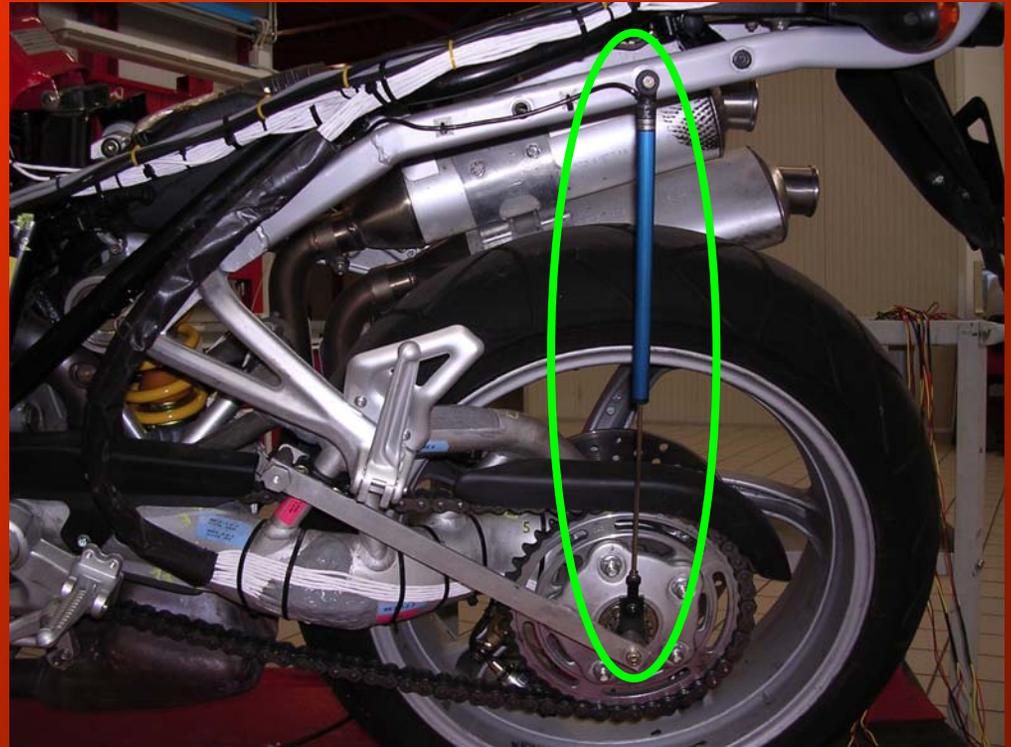






**STRUMENTAZIONE
DEL MOTOCICLO
CON POTENZIOMETRI**

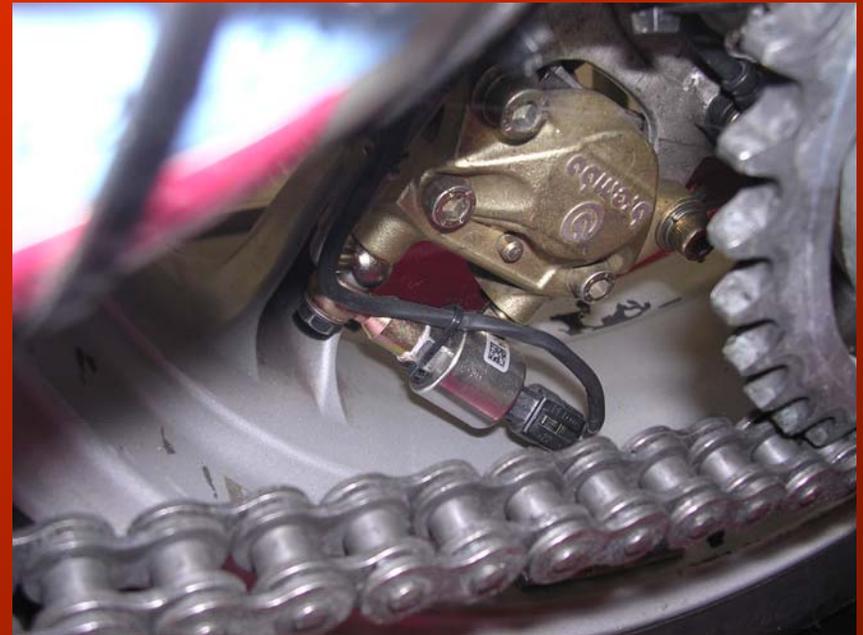
POTENZIOMETRI LINEARI



STRUMENTAZIONE DEL MOTOCICLO CON :

- **SENSORI DI PRESSIONE PINZE DEI FRENI**
 - **SENSORE DI VELOCITA'**
- **SENSORE DI APERTURA VALVOLA A FARFALLA**
- **SENSORE VELOCITA' ANGOLARE MOTORE**

SENSORI DI PRESSIONE PINZE DEI FRENI



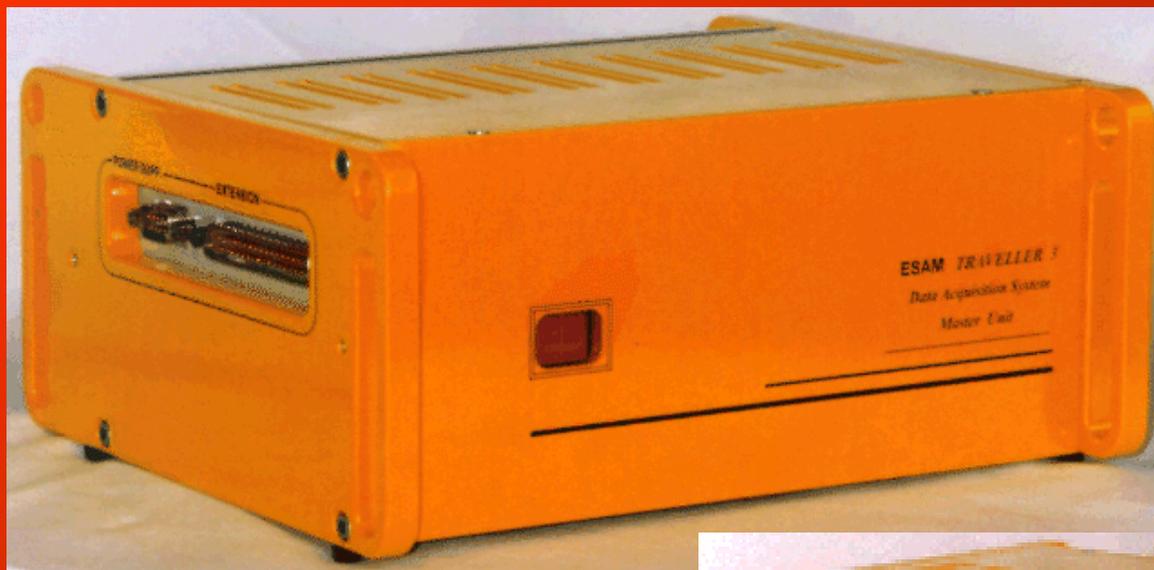
SENSORE DI VELOCITA'



- **SENSORE DI APERTURA VALVOLA A FARFALLA**
- **SENSORE VEL. ANGOLARE MOTORE**



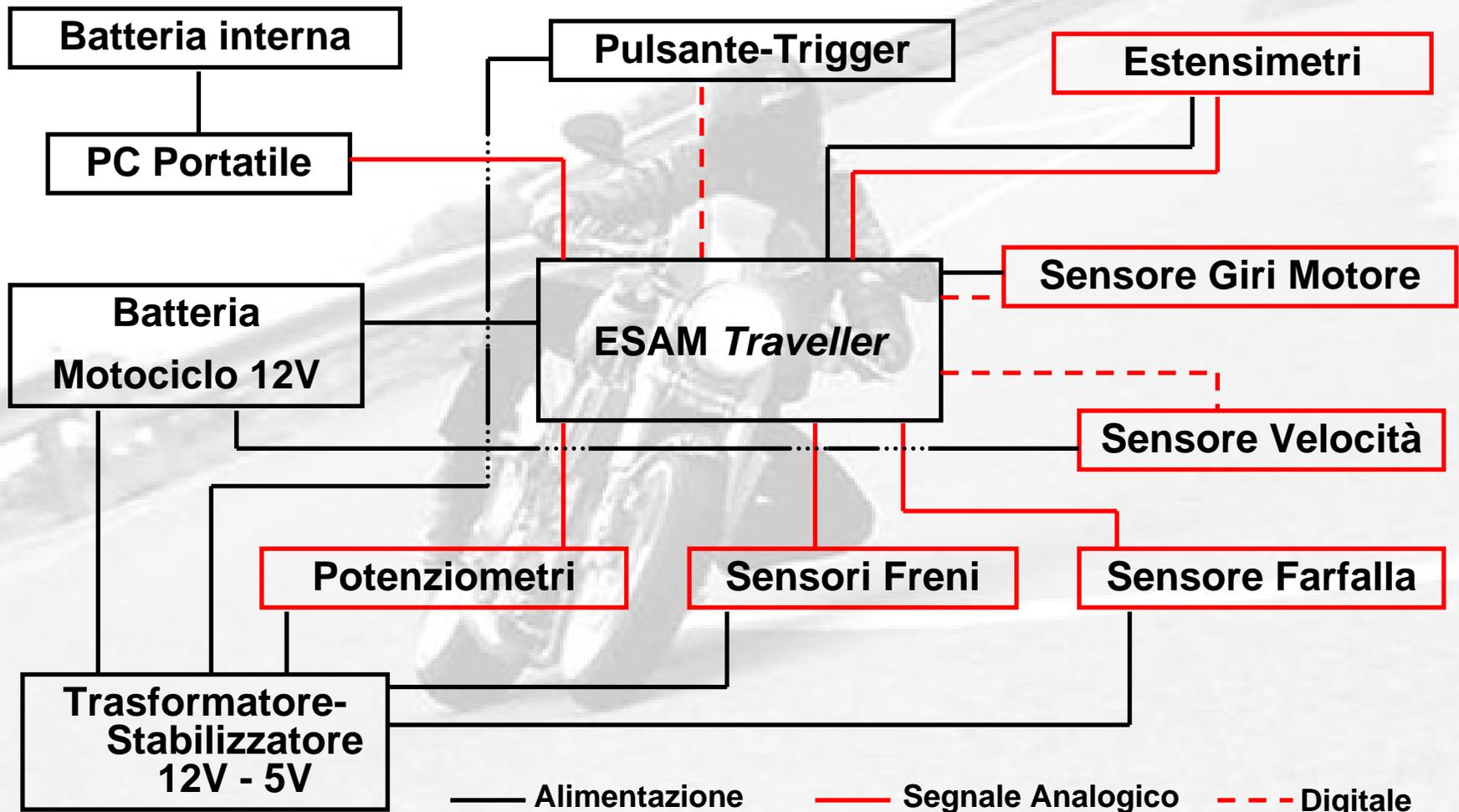
CENTRALINA DI ACQUISIZIONE DATI



Pulsante Trigger



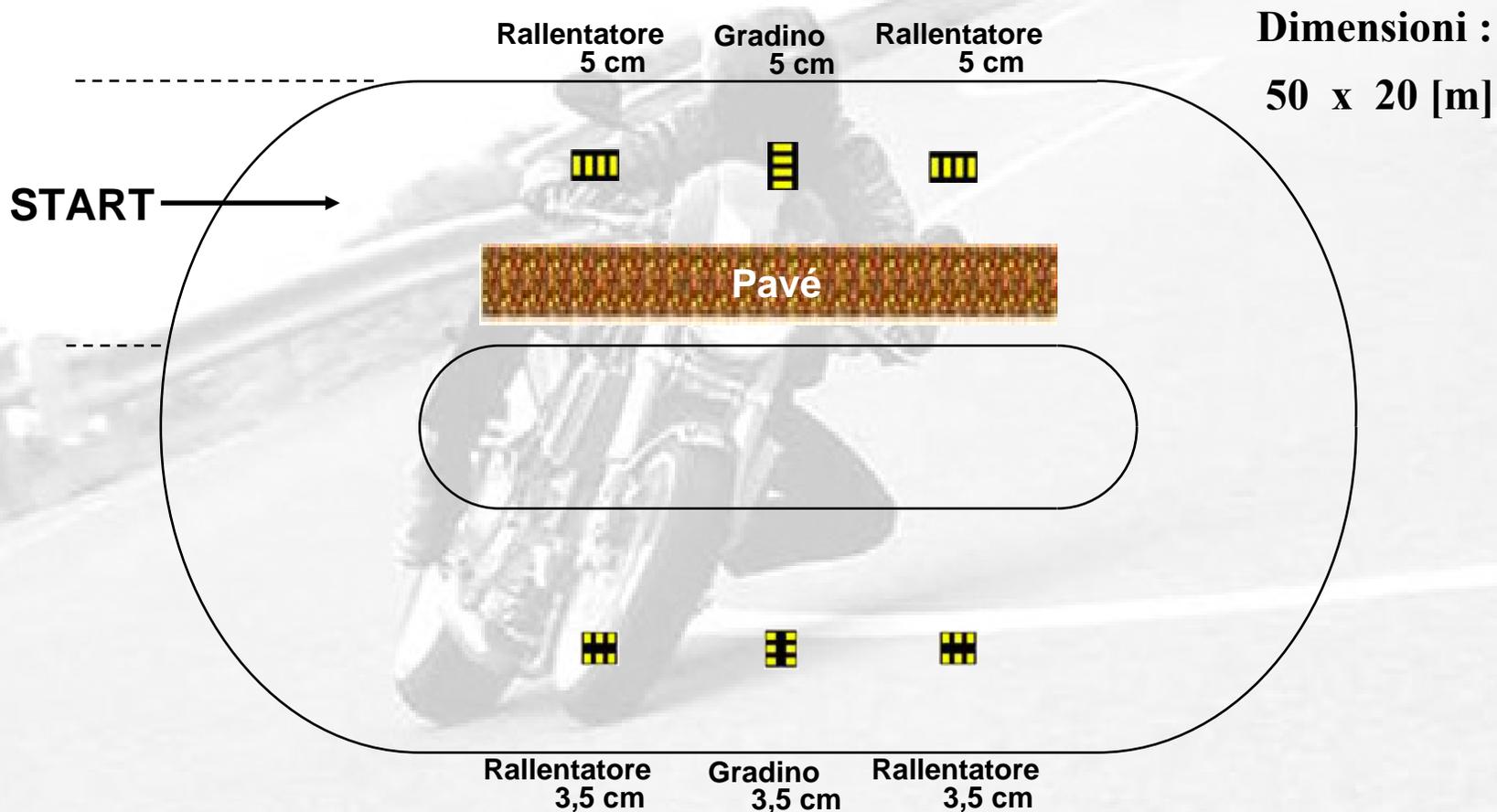
SCHEMA DELLA STRUMENTAZIONE COMPLETA





**PROVE SPERIMENTALI
SU CIRCUITO INTERNO ALLO
STABILIMENTO DUCATI**

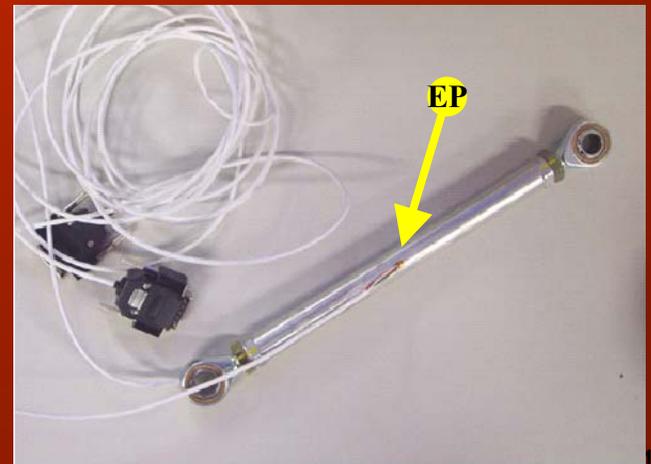
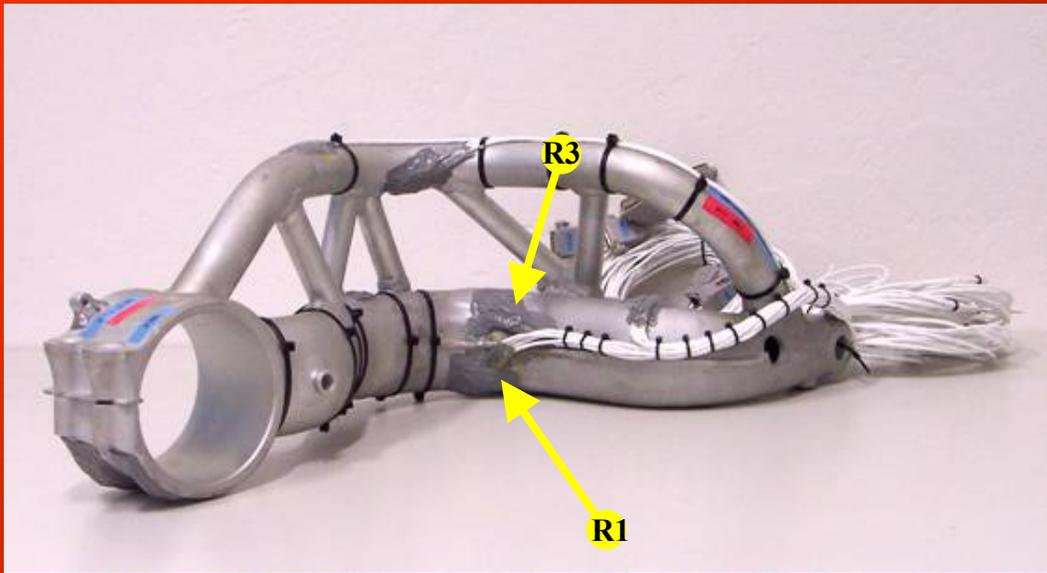
IL CIRCUITO





**RISULTATI DELLE PROVE
SPERIMENTALI**

DUCATI



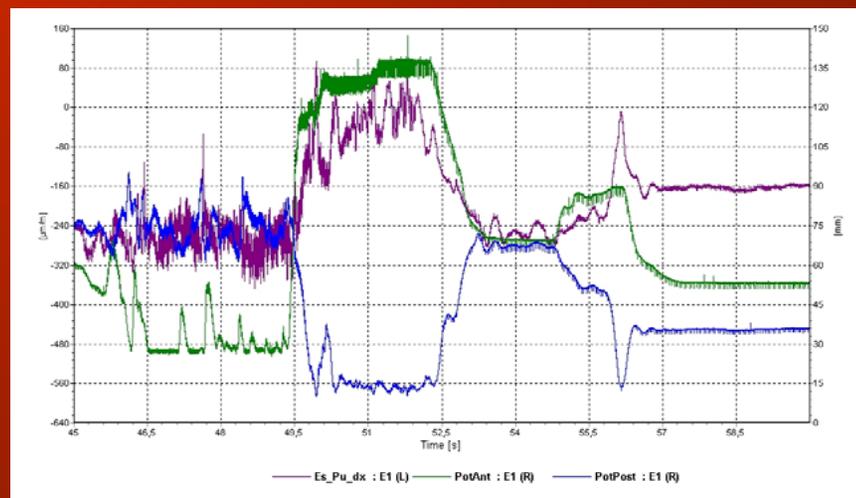
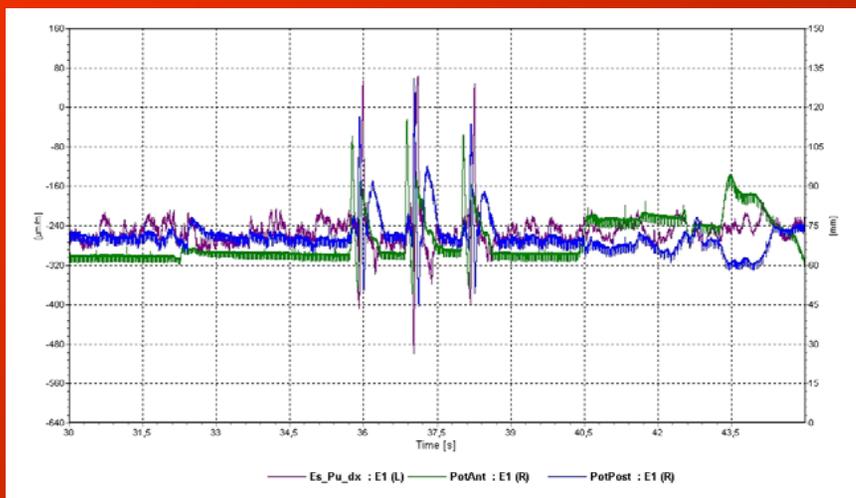
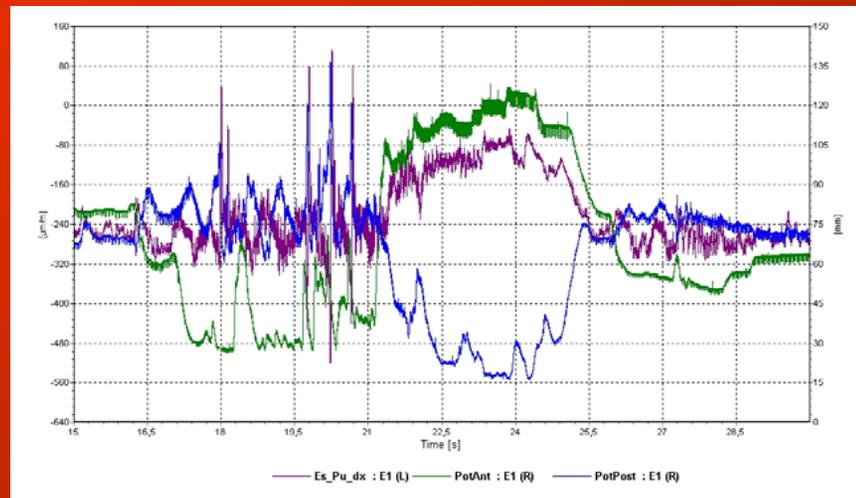
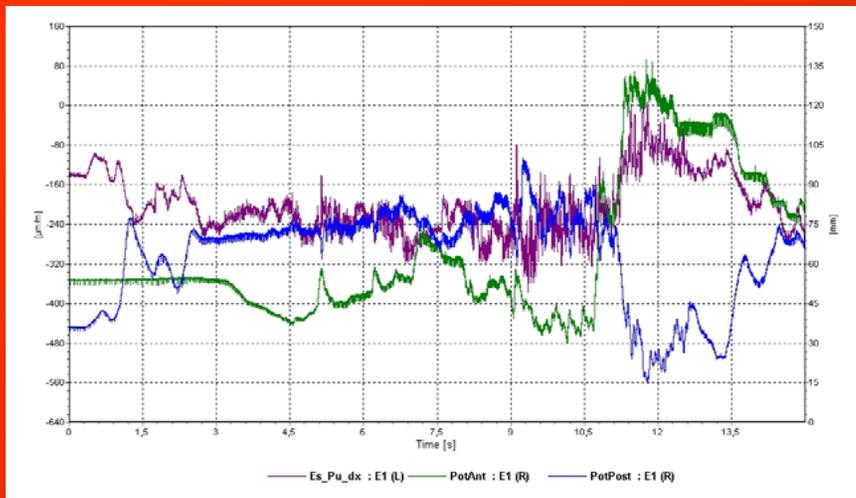
DUCATI



ESTENS PUNTONE

POT ANT

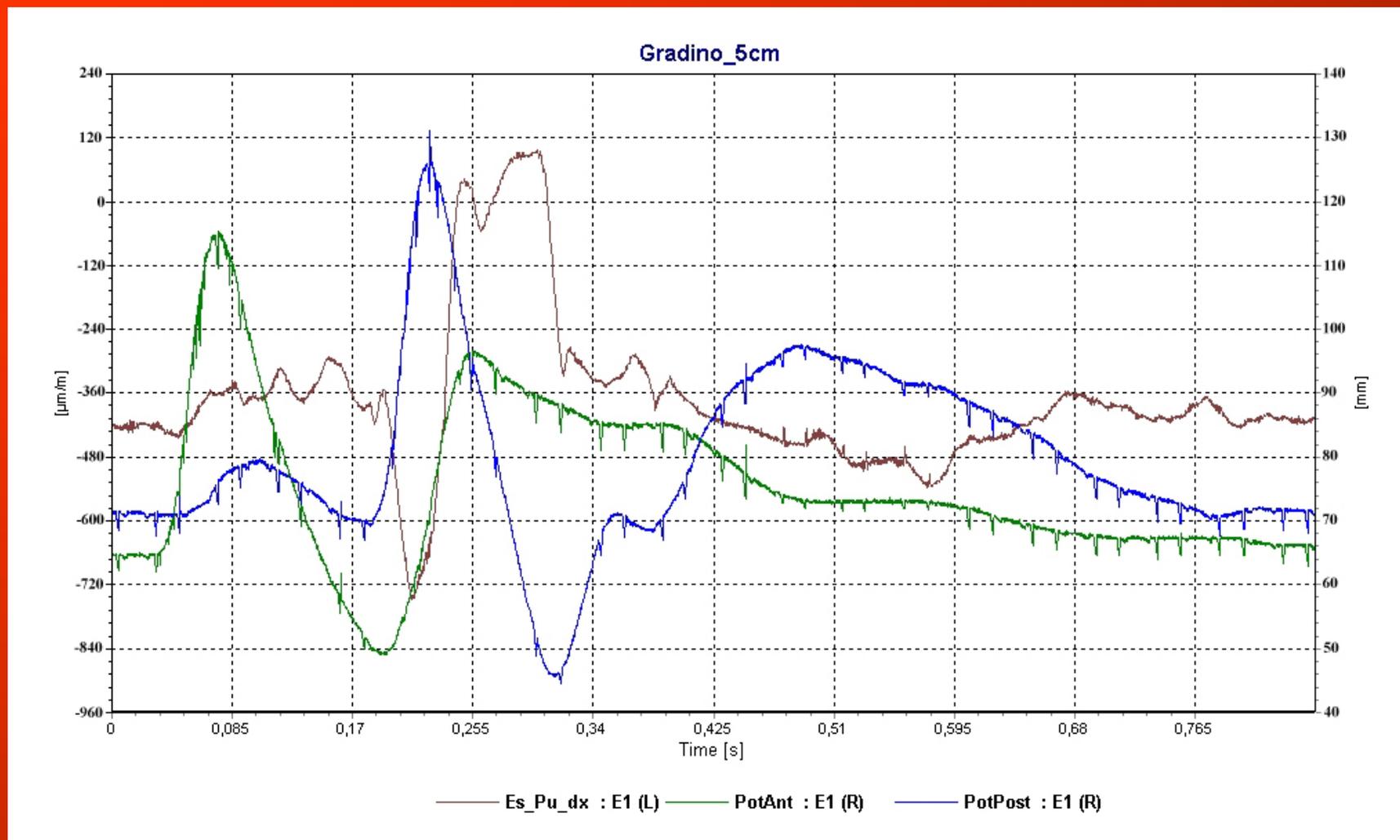
POT POST



ESTENS PUNTONE

POT ANT

POT POST



Grazie alle informazioni ottenute dall'estensimetro posto sul puntone della sospensione posteriore si è potuto risalire alla forza agente su tale componente utile per la verifica di resistenza delle strutture e per la validazione del modello MULTY-BODY

$$\sigma = \varepsilon \cdot E \quad F = \sigma \cdot A$$

Evento	$\mu\varepsilon$ [microdef.]	Tensioni [Pa]	Forza [N]
Gradino 5 cm 40 km/h	$744 \cdot 10^{-6}$	54'312'000	13'056,94425
Gradino 3,5 cm 70 km/h	$520 \cdot 10^{-6}$	37'960'000	9'125,82125
Gradino 5 cm 30 km/h	$498 \cdot 10^{-6}$	36'354'000	8'739,7288125
Rallentatore 3,5 cm 70 km/h	$451 \cdot 10^{-6}$	32'923'000	7'914,89496875
Rallentatore 5 cm 30 km/h	$408 \cdot 10^{-6}$	29'784'000	7'160,25975

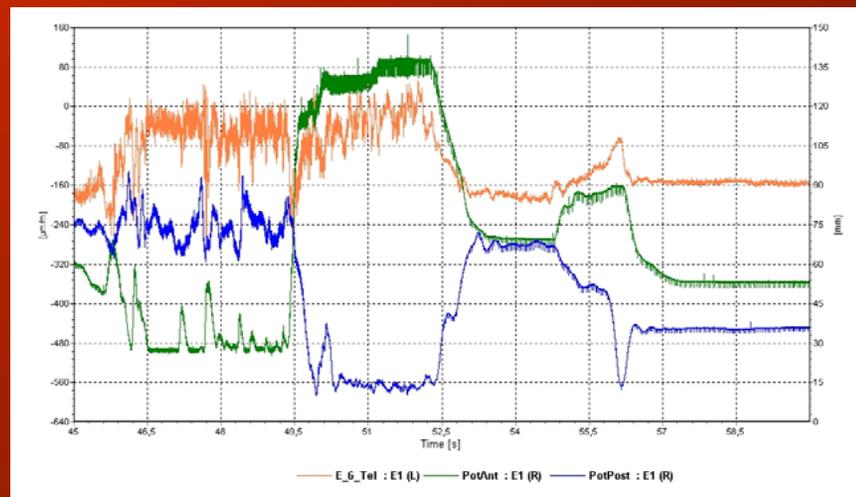
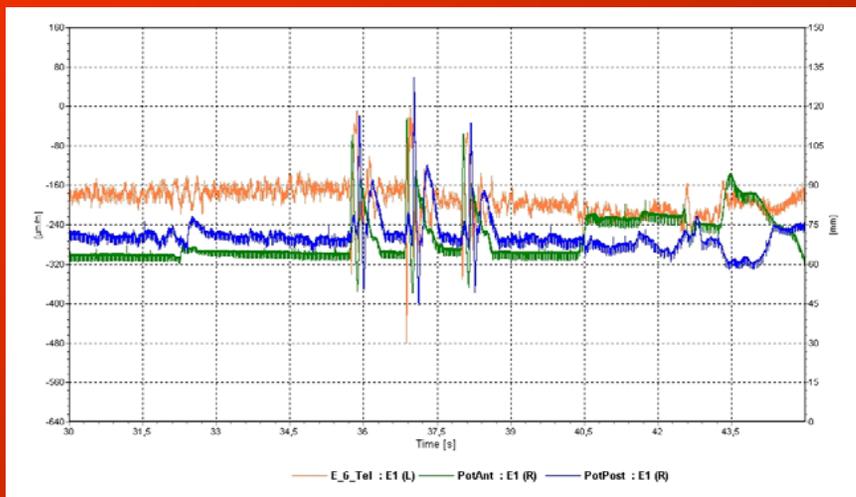
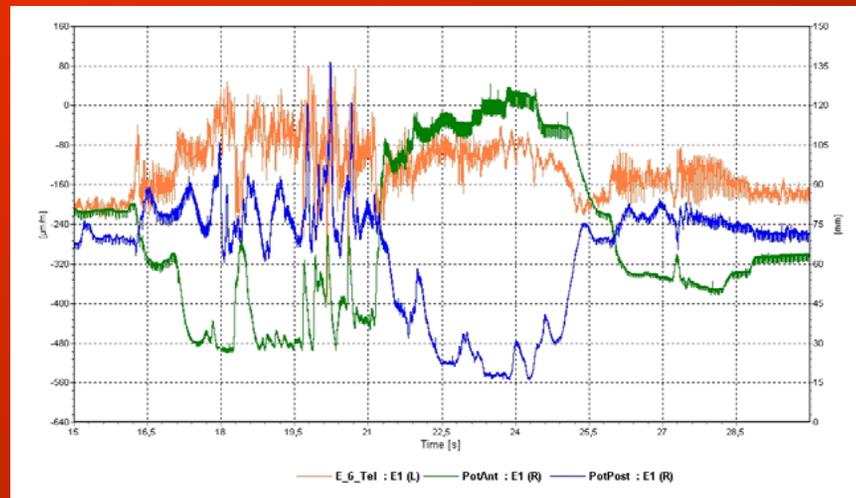
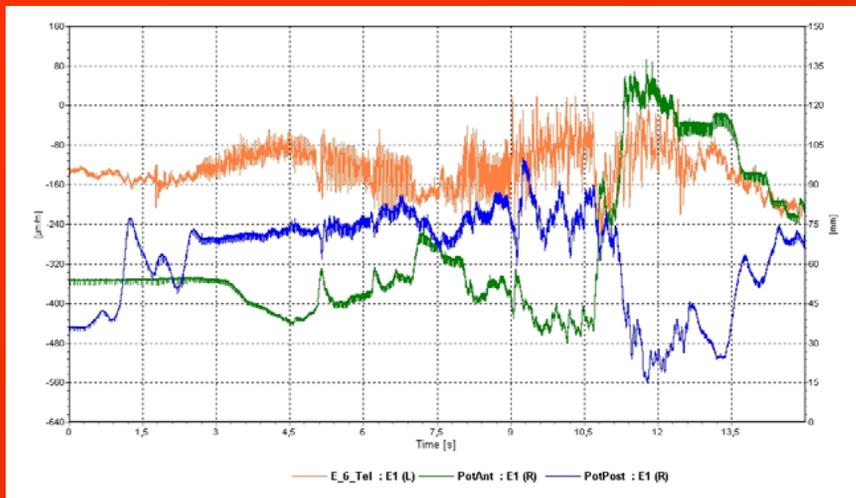
$$E = 73'000'000'000 \text{ Pa}$$

$$A = 0,00024040625 \text{ m}^2$$

ESTENS 6 TELAIO

POT ANT

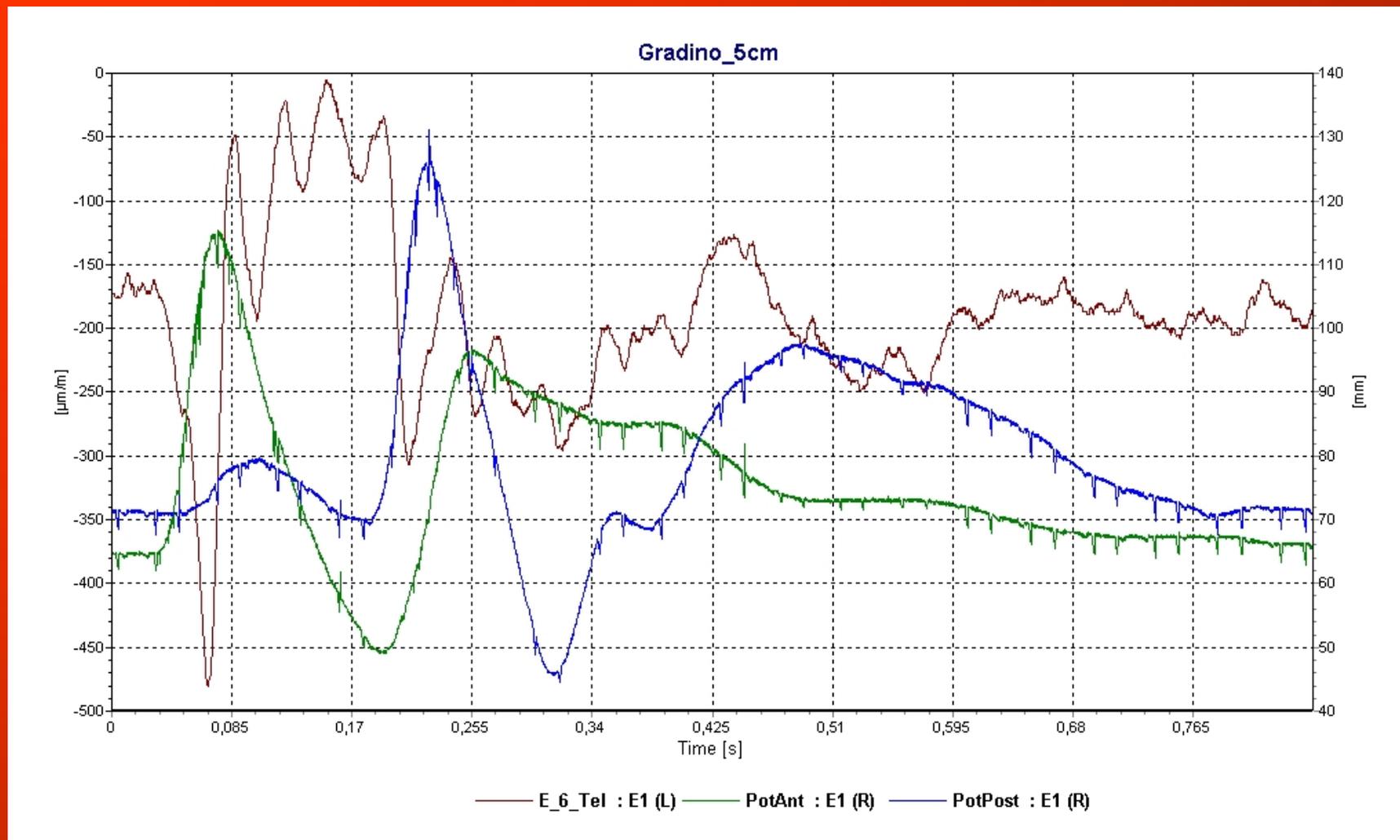
POT POST



ESTENS 6 TELAIO

POT ANT

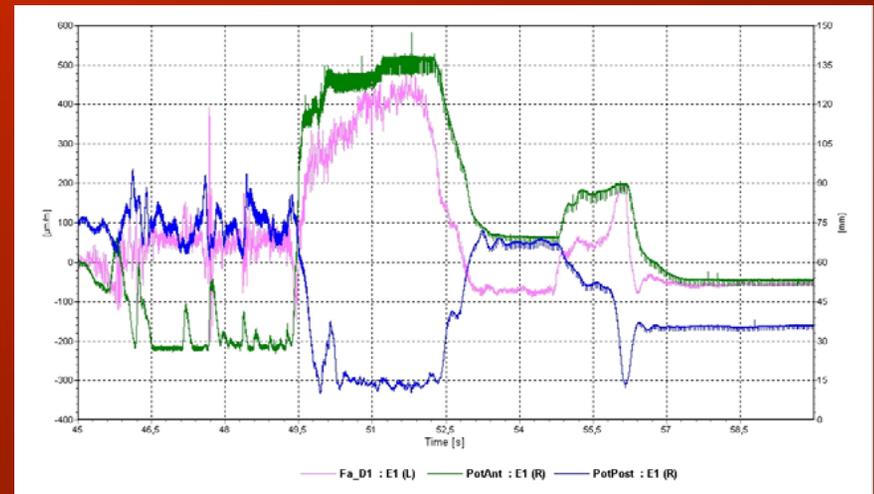
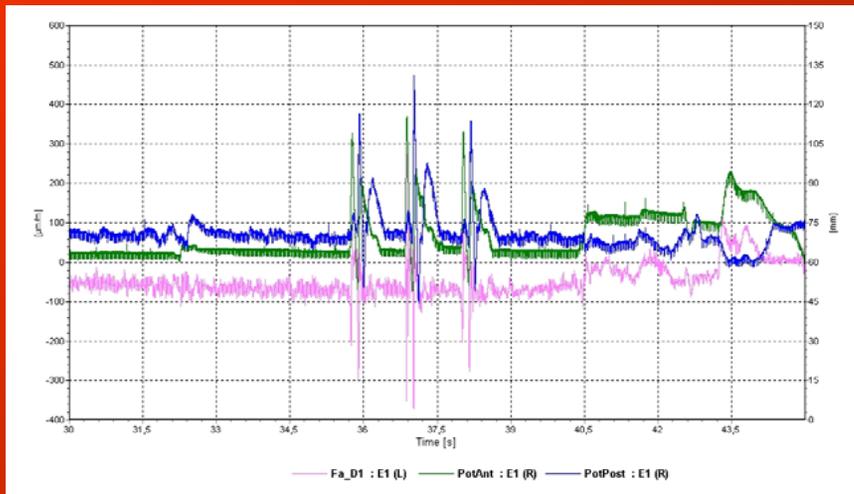
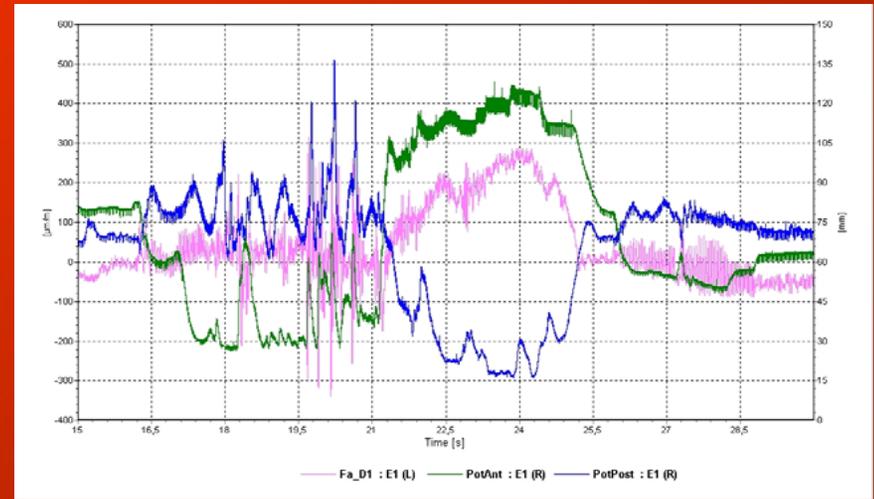
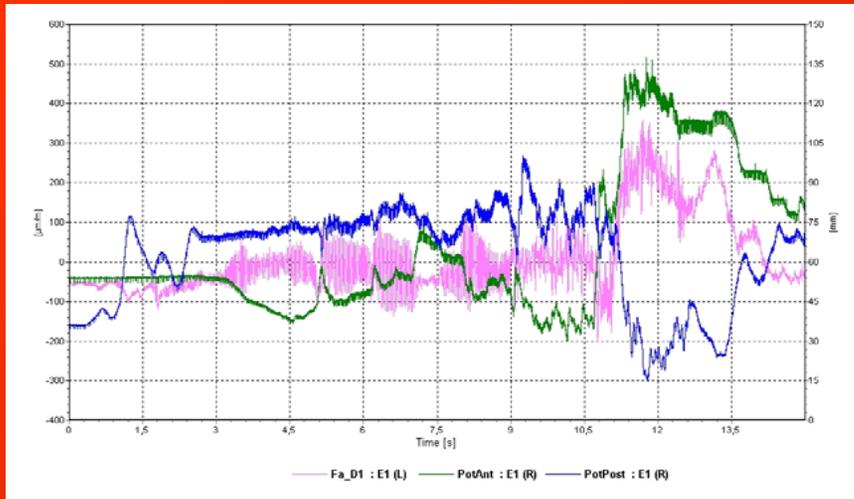
POT POST



ESTENS Fa D1 FORC

POT ANT

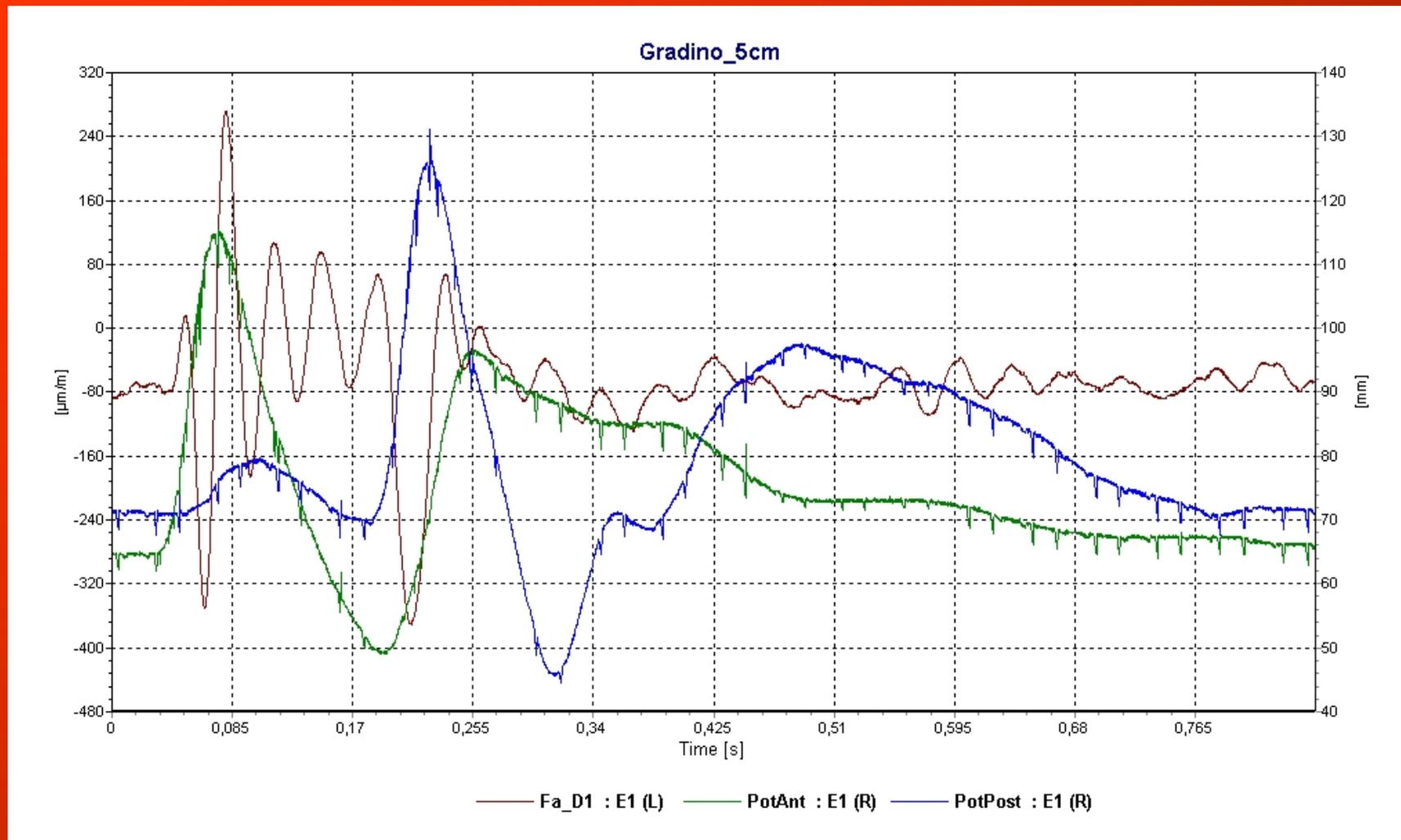
POT POST



ESTENS Fa D1 FORC

POT ANT

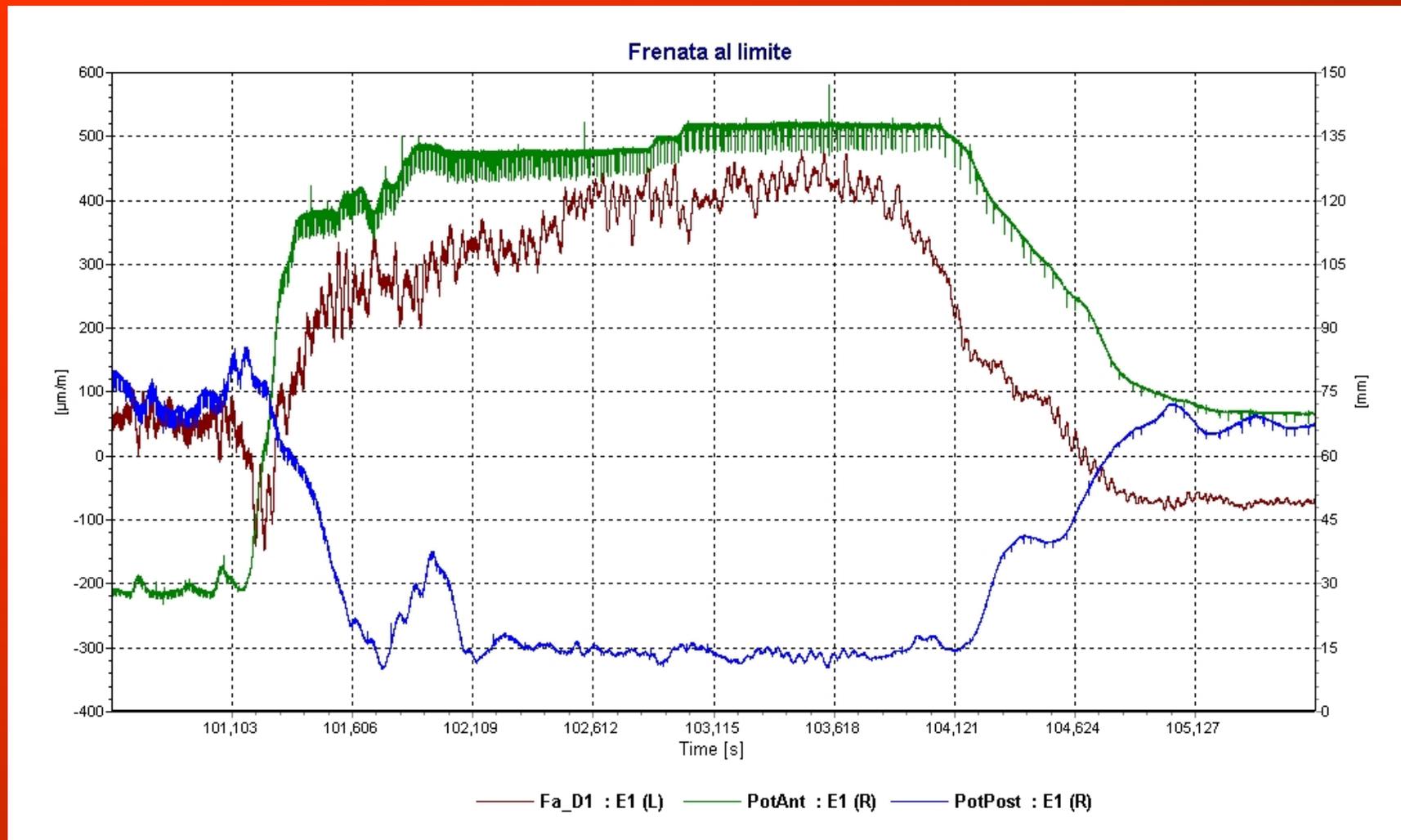
POT POST



ESTENS Fa D1 FORC

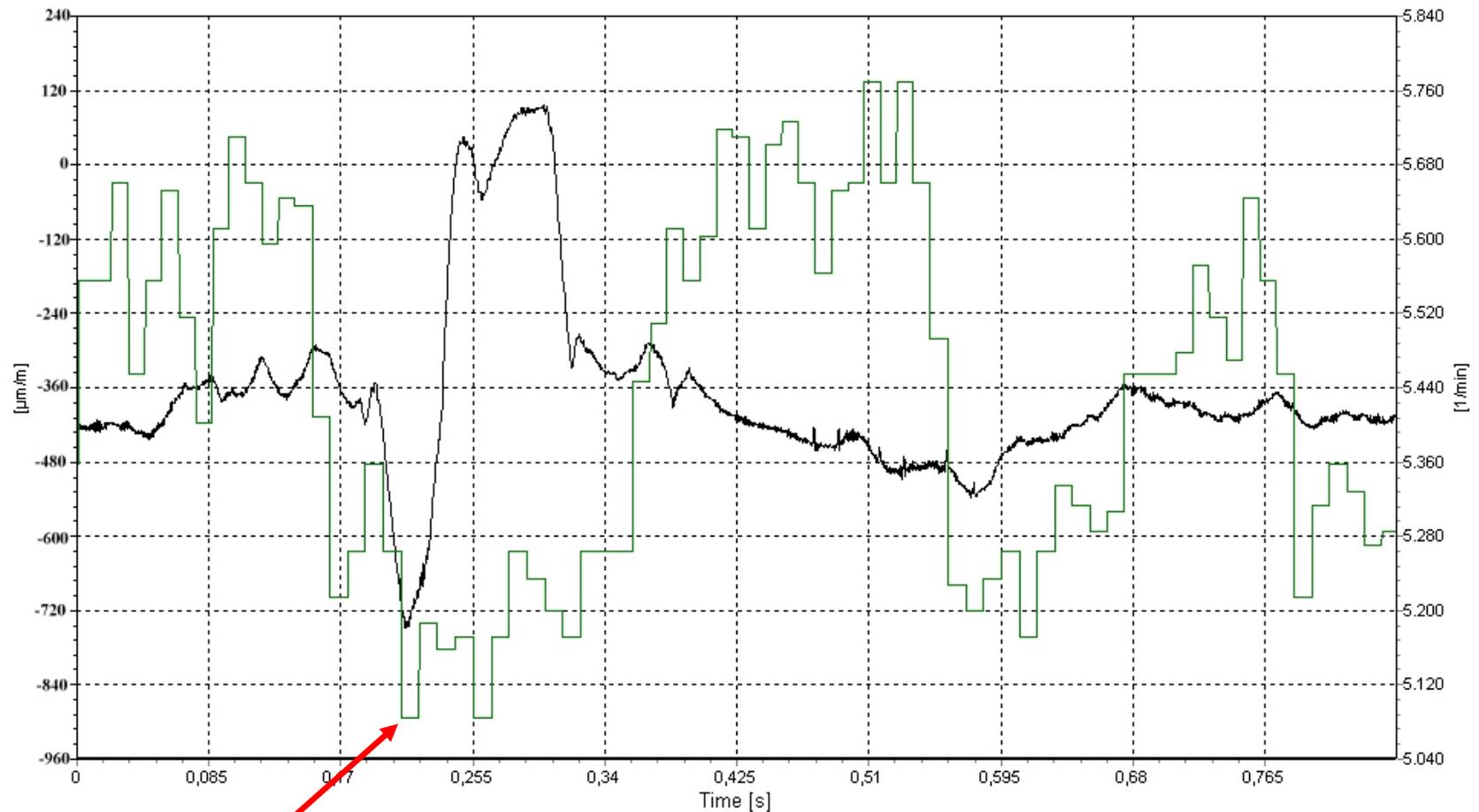
POT ANT

POT POST



GIRI MOTORE

ESTENS PUNTONE



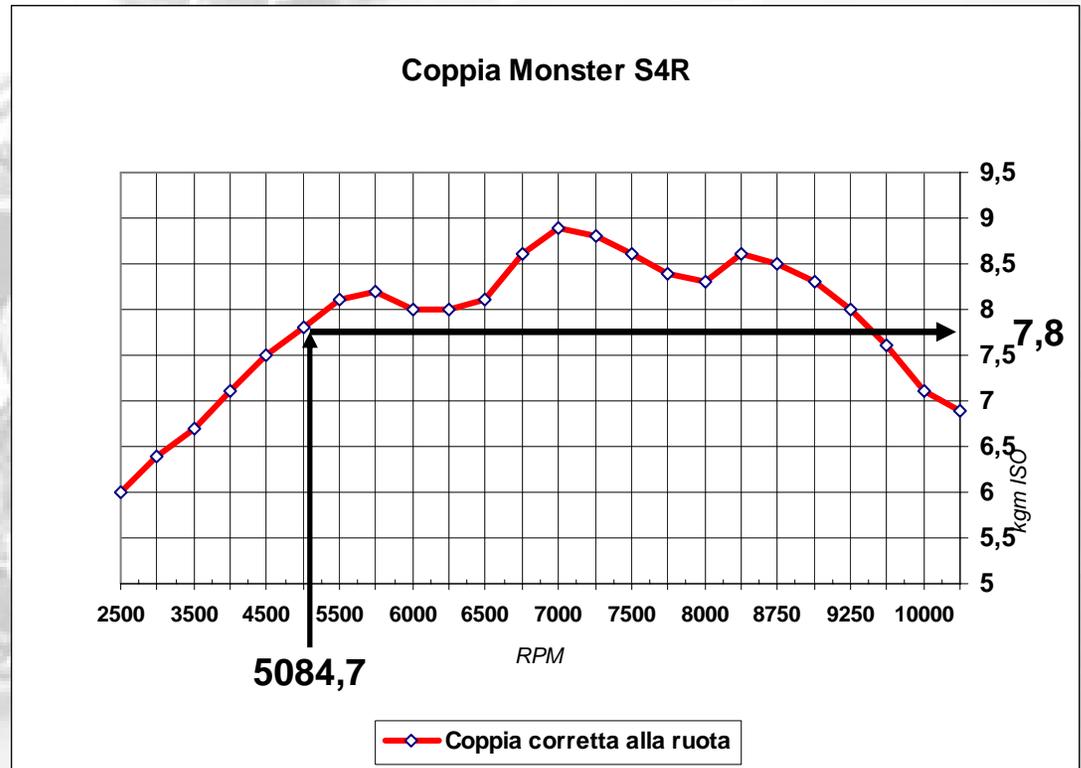
5'084,7 rpm

— Es_Pu_dx : E1 (L) — 1001 : E1 (R)

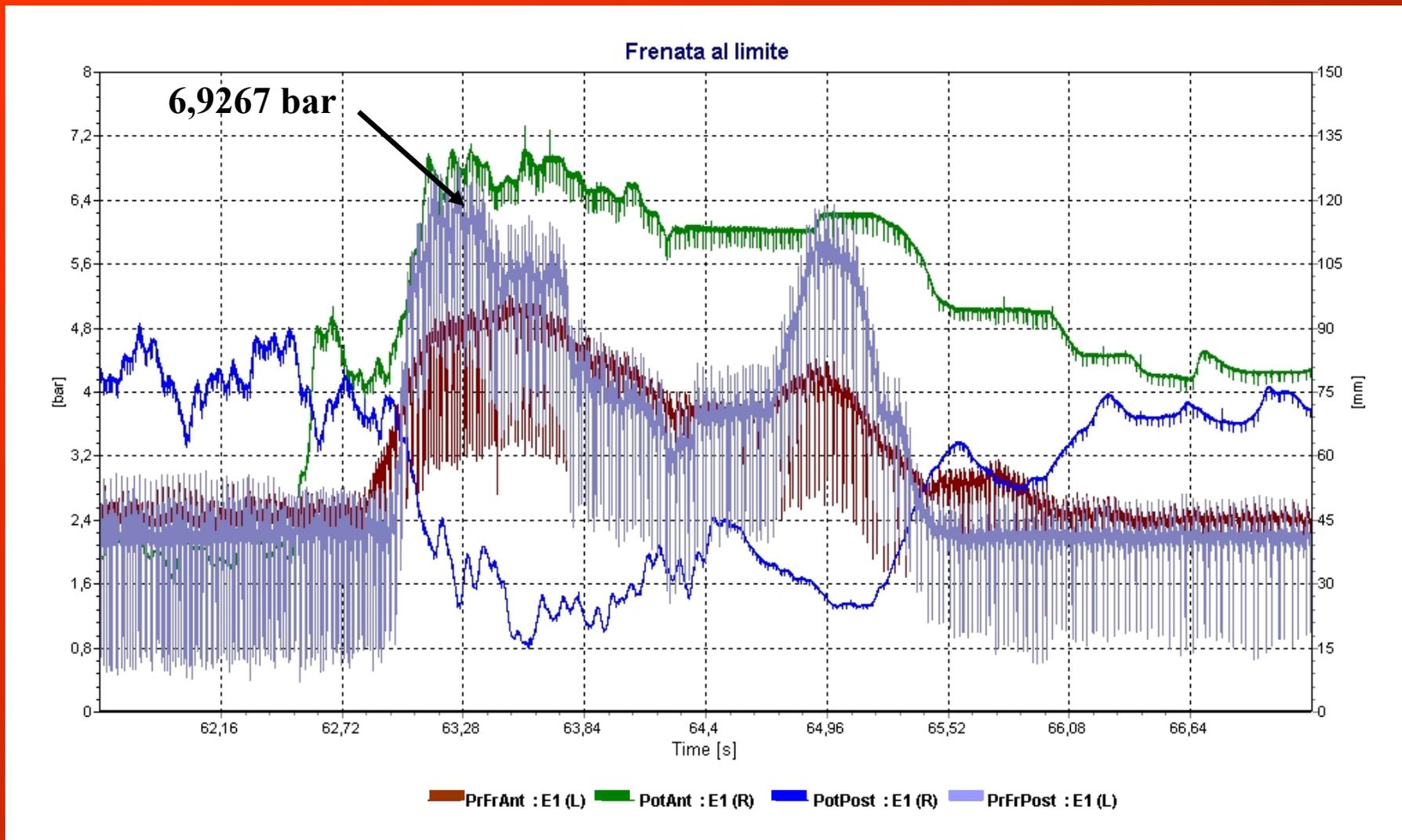
Grazie al sensore conta giri motore si è trovato il valore della forza del tiro catena nel momento di impatto contro il gradino di 5 cm utile per la verifica di resistenza del forcellone.

$$7,8 \cdot 9,81 = 76,518 \text{ N}\cdot\text{m}$$

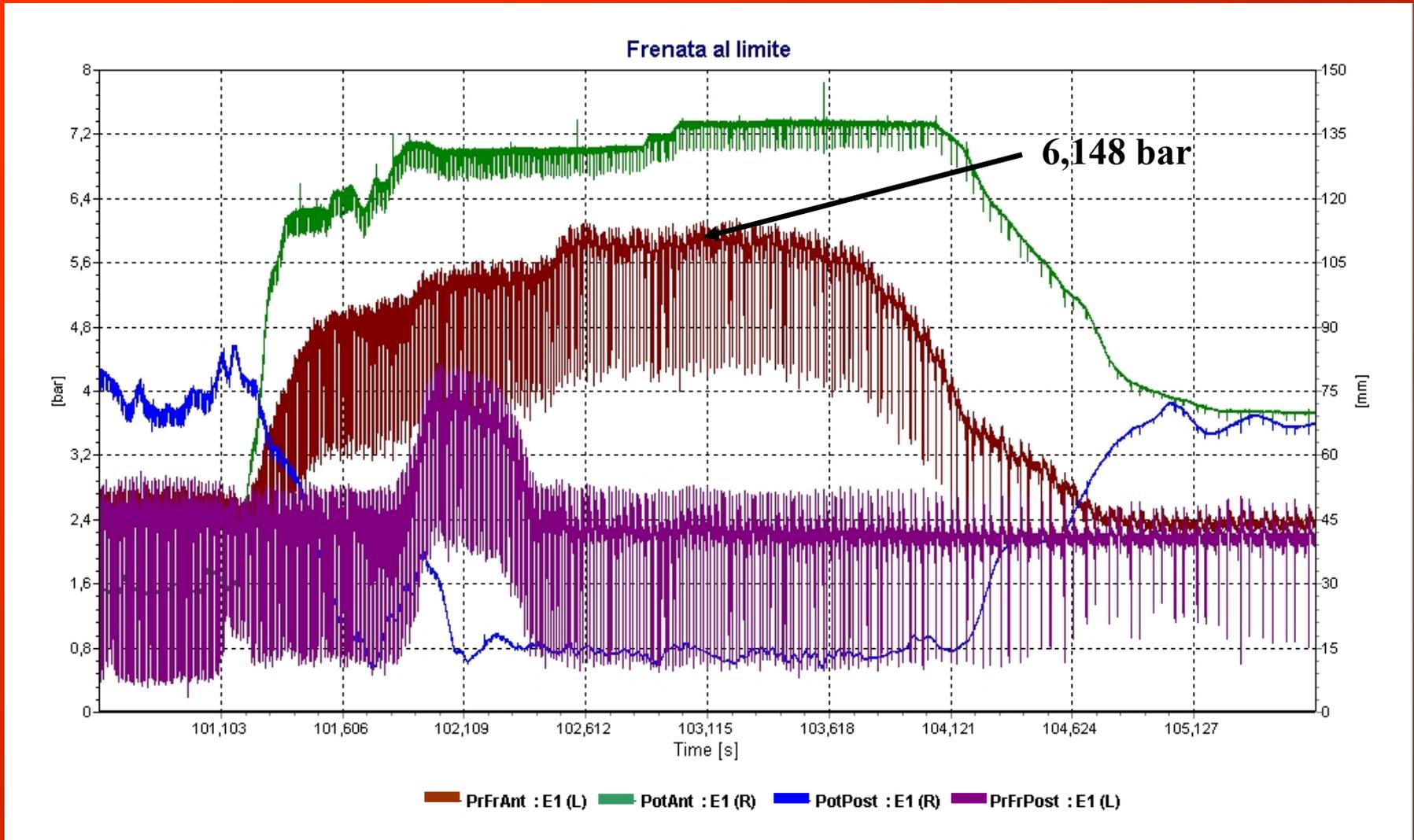
$$T = \frac{76,518}{r_c} = \frac{76,518}{0,105} = 728,74 \text{ N}$$



ANDAMENTO DELLE PRESSIONI NELLE PINZE FRENI



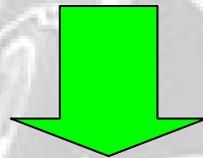
ANDAMENTO DELLE PRESSIONI NELLE PINZE FRENI



Forze in frenata



**NELL'INDUSTRIA DEI TRASPORTI, LA NECESSITA' DI
COMPETERE IN UN MERCATO CARATTERIZZATO
DA COMPETITORI SEMPRE PIU' AGGUERRITI,
SPINGE LE AZIENDE AD UN'AZIONE VOLTA ALLA
RIDUZIONE DEL TEMPO DI SVILUPPO DEL
PRODOTTO**



PROTOTIPAZIONE VIRTUALE

LA PROTOTIPAZIONE VIRTUALE RICHIEDE:

- **L'INDIVIDUAZIONE DEI CARICHI AGENTI SUI COMPONENTI**
 - **LA CREAZIONE DI UN MODELLO GEOMETRICO VIRTUALE DI OGNI SINGOLO COMPONENTE**
 - **L'APPLICAZIONE SUL MODELLO VIRTUALE DEI VINCOLI E DEI CARICHI**
 - **LA VERIFICA DI RESISTENZA DEI COMPONENTI IN ESAME**



**PER INDIVIDUARE I CARICHI AGENTI
SUI SINGOLI COMPONENTI CI SI
AVVALE DI UN
MODELLO DINAMICO
MULTI-BODY**

**CON IL MODELLO DINAMICO
SI POSSONO INDIVIDUARE:**

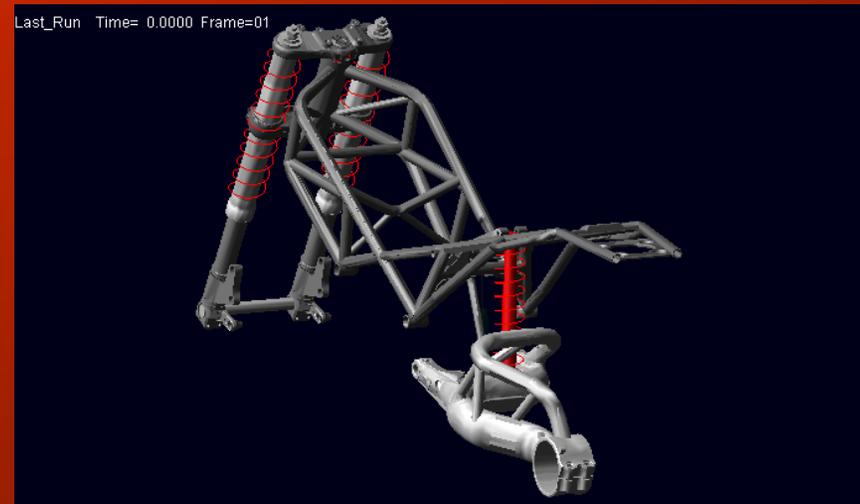
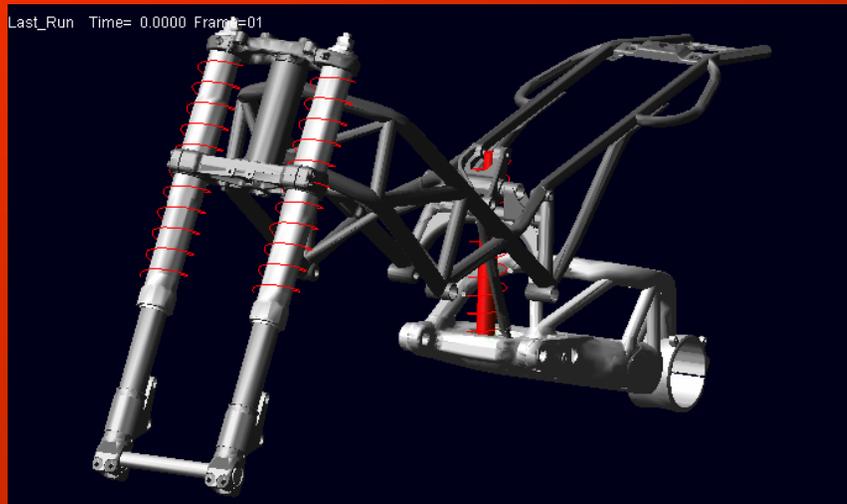
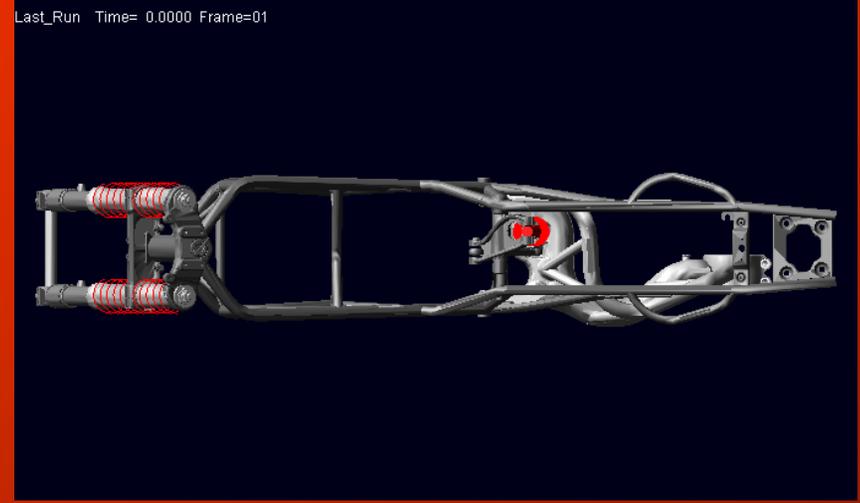
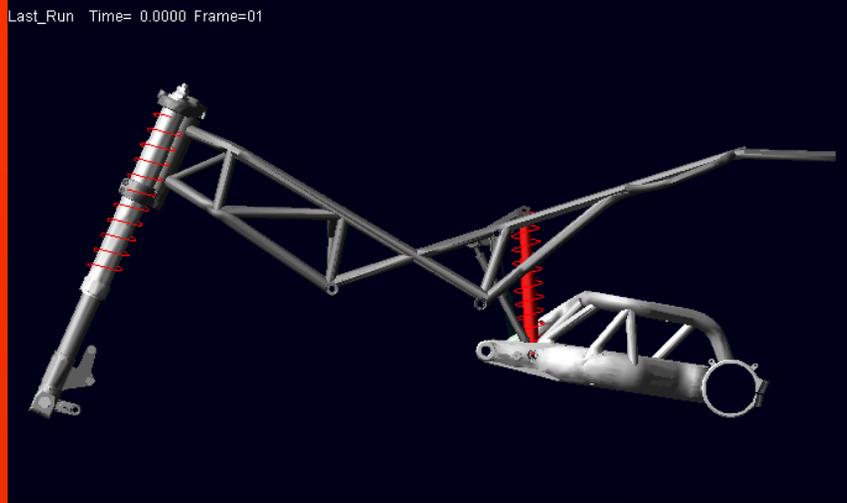
- **SPOSTAMENTI**
- **VELOCITA'**
- **ACCELERAZIONI**
- **FORZE**

AGENTI SUI VARI COMPONENTI

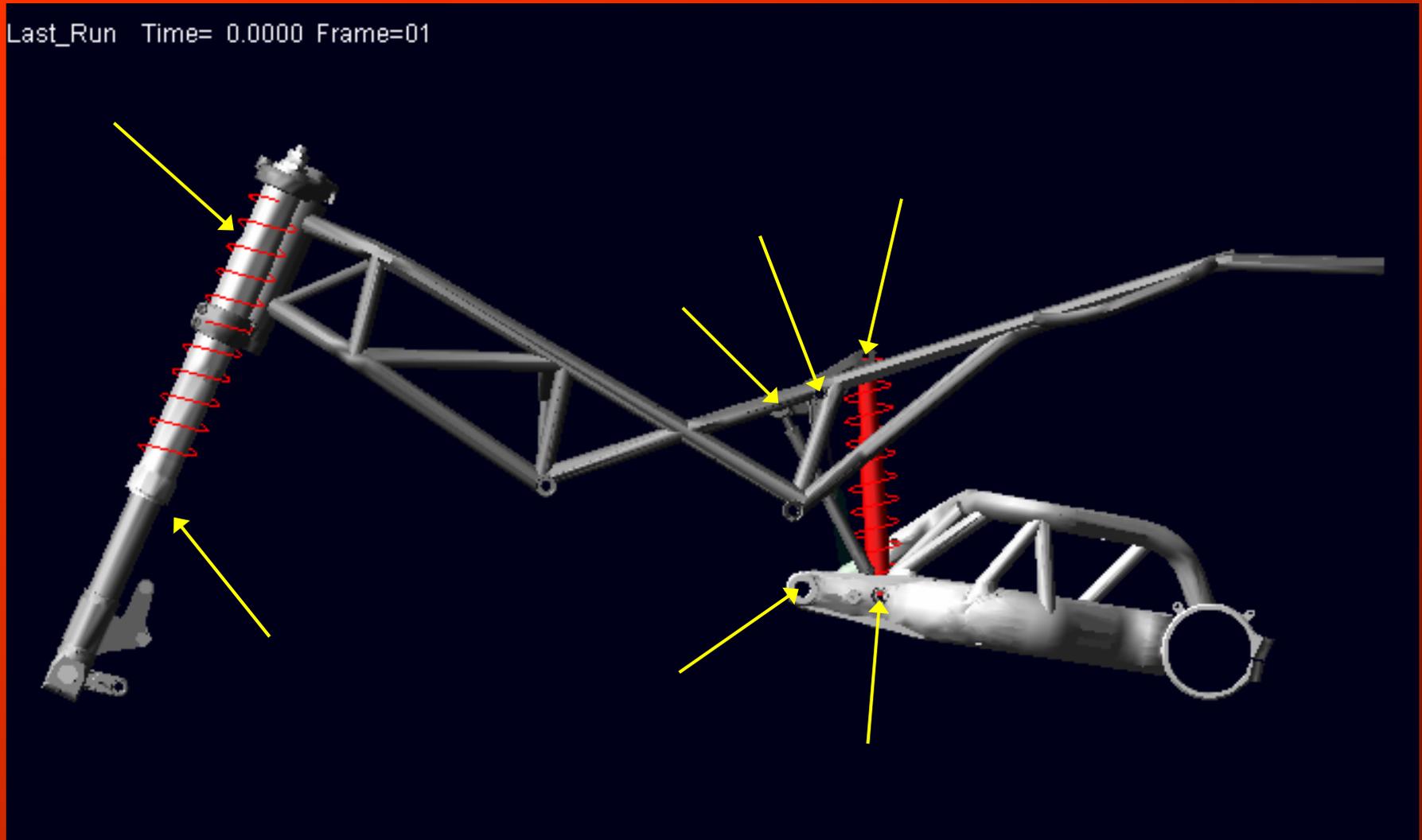
PROCEDURA:

- **COSTRUZIONE DEL MODELLO DINAMICO**
- **DEFINIZIONE DEI VINCOLI CINEMATICI**
- **IMPOSIZIONE DELLA LEGGE DI MOTO**
- **ACQUISIZIONE DEI RISULTATI**

COSTRUZIONE DEL MODELLO



DEFINIZIONE DEI VINCOLI

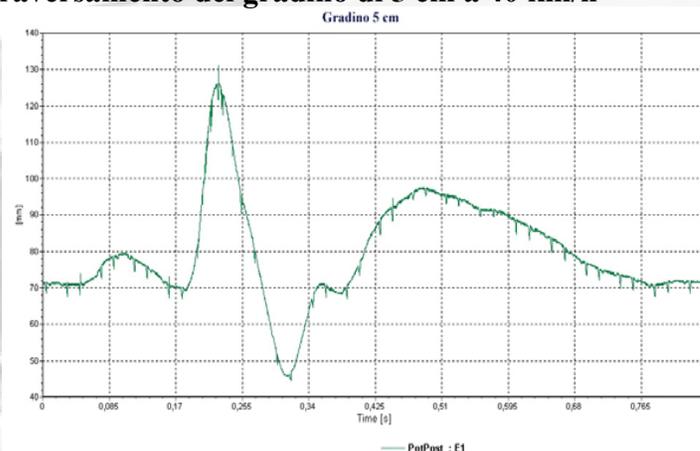
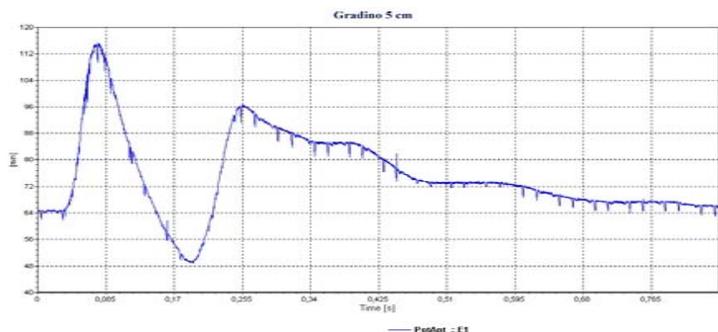


IMPOSIZIONE DELLA LEGGE DI SPOSTAMENTO

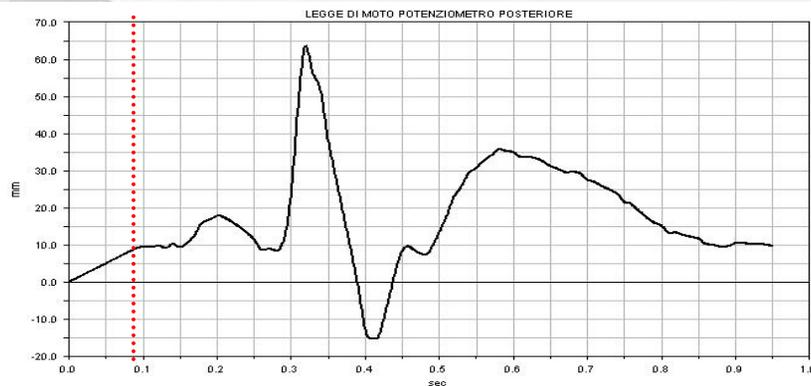
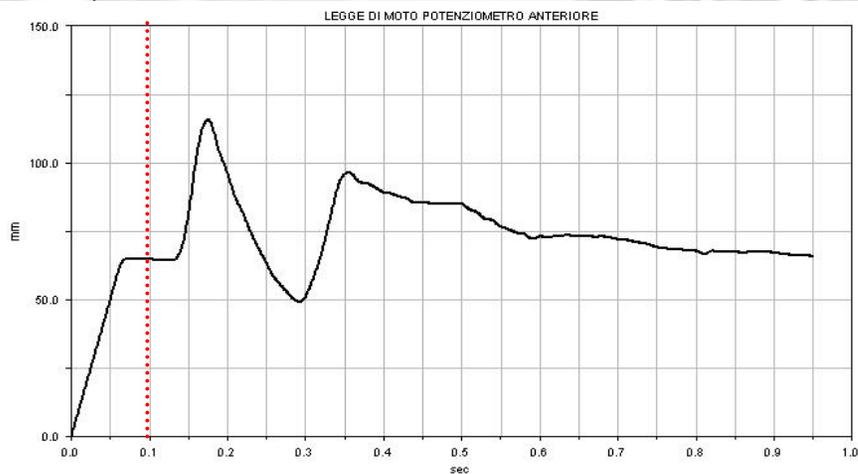
- 1) **INDIVIDUAZIONE DELL'EVENTO DA SIMULARE**
- 2) **FILTRAGGIO DEL SEGNALE ACQUISITO DAI POTENZIOMETRI**
- 3) **ASSEGNAZIONE DELLA LEGGE DI MOTO AL MODELLO**

IMPOSIZIONE DELLA LEGGE DI SPOSTAMENTO

1) INDIVIDUAZIONE DELL'EVENTO DA SIMULARE: Attraversamento del gradino di 5 cm a 40 km/h

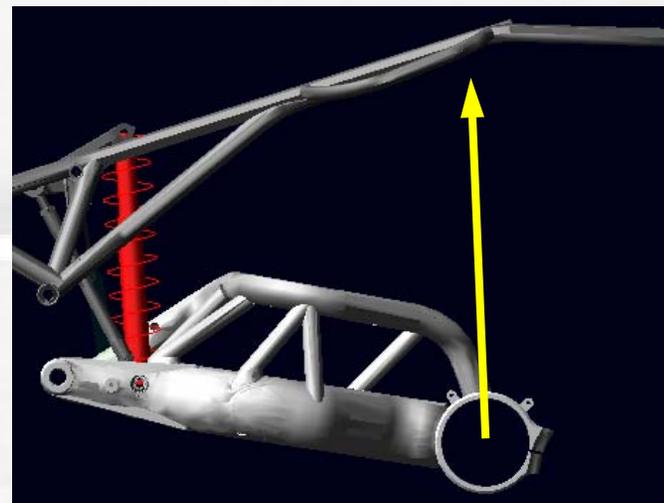
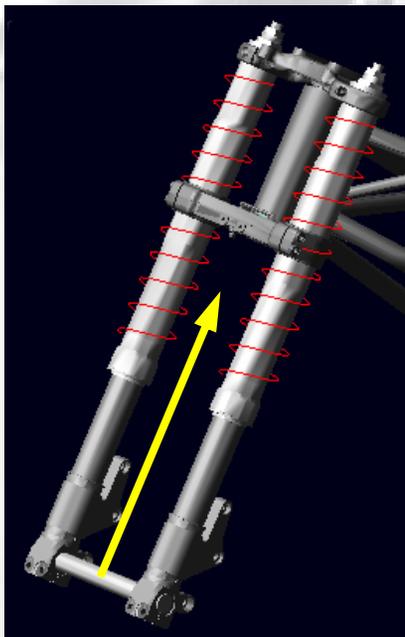


2) FILTRAGGIO DEL SEGNALE ACQUISITO DAI POTENZIOMETRI



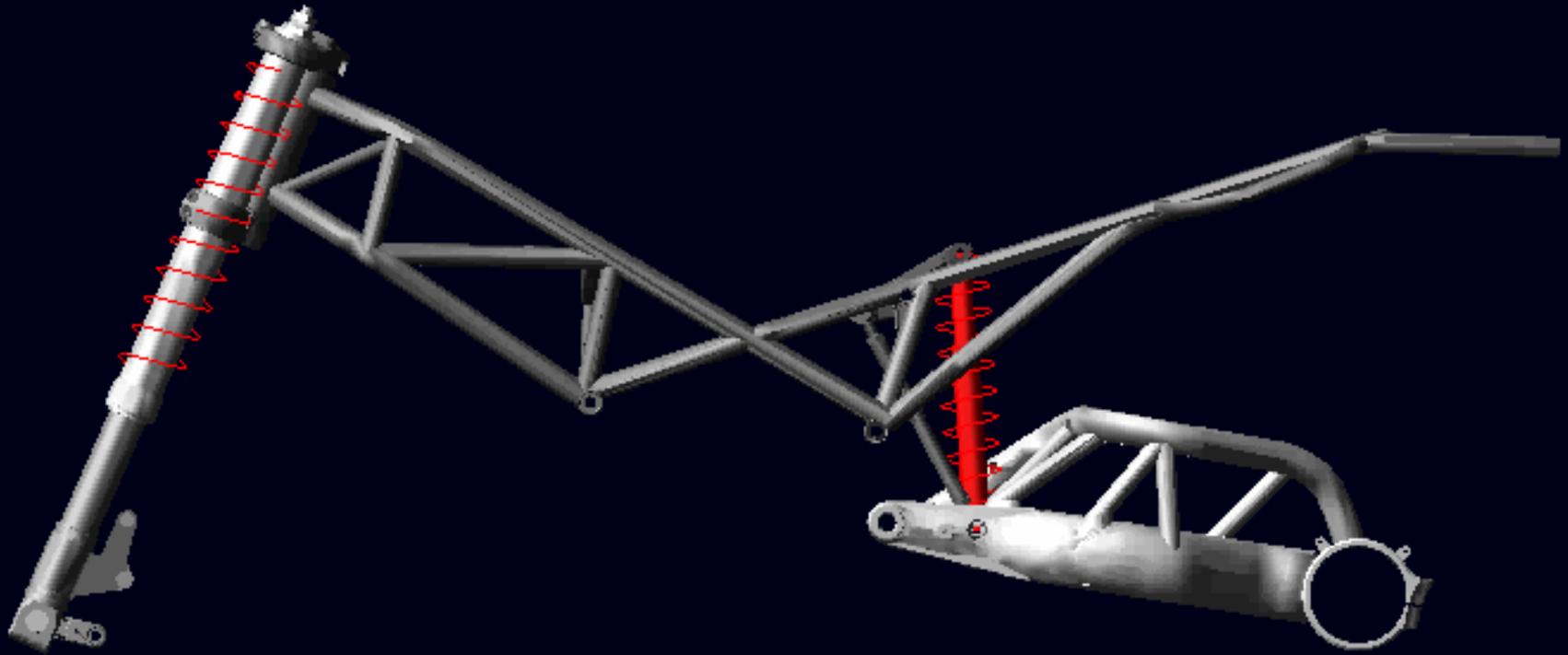
IMPOSIZIONE DELLA LEGGE DI SPOSTAMENTO

3) ASSEGNAZIONE DELLA LEGGE DI SPOSTAMENTO AL MODELLO



IMPOSIZIONE DELLA LEGGE DI SPOSTAMENTO

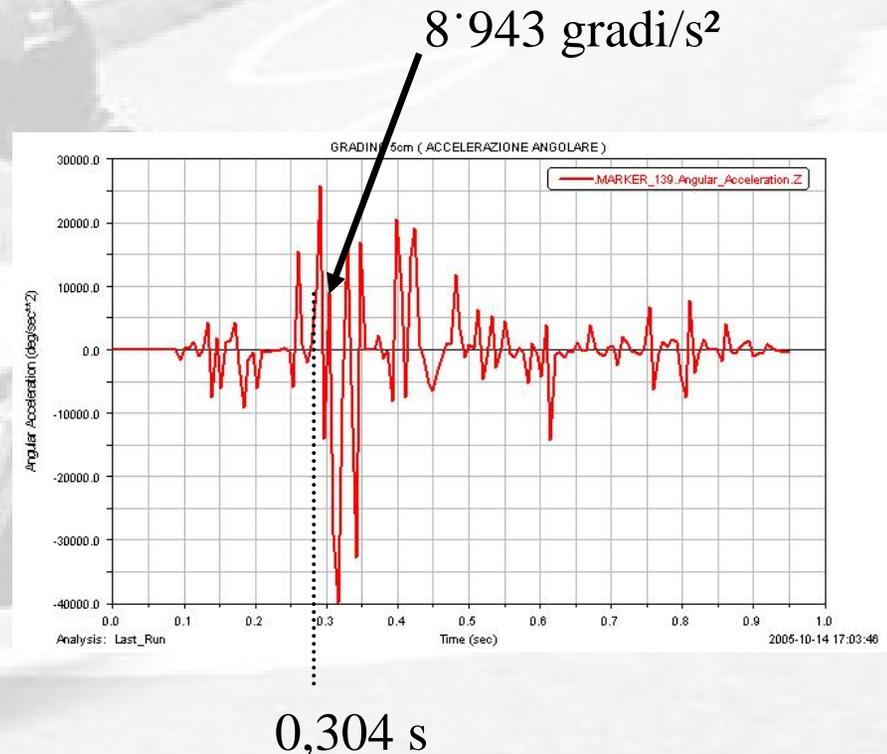
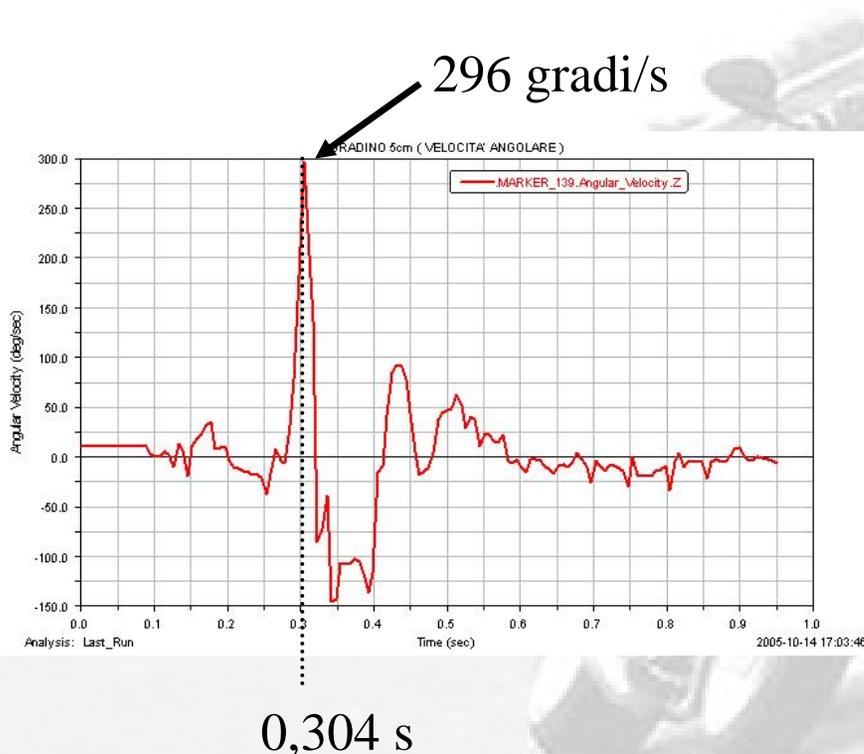
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ACQUISIZIONE DEI RISULTATI

ATTRAVERSAMENTO DEL GRADINO DI 5 CM A 40 km/h

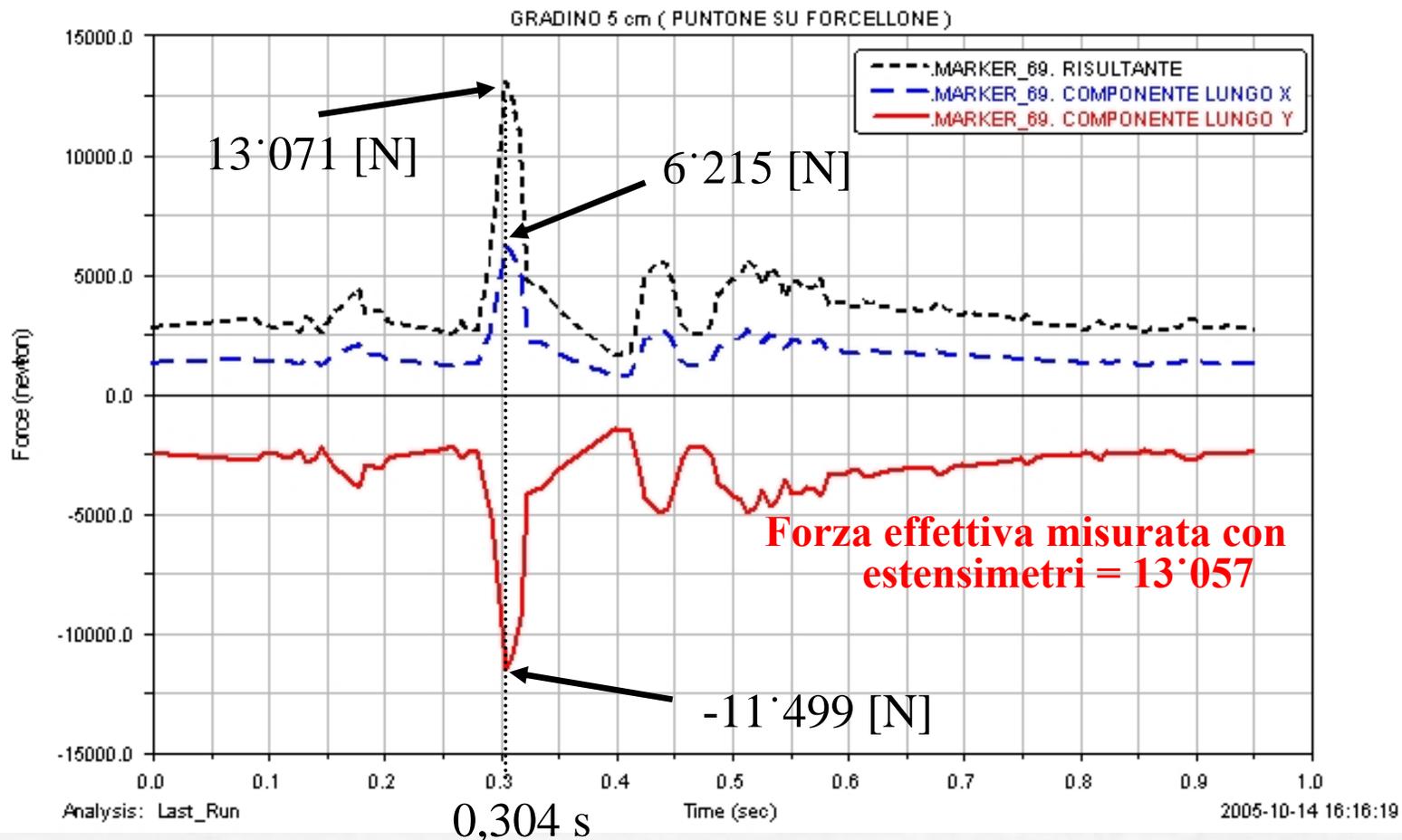
Andamento della velocità ed accelerazione angolare del forcellone



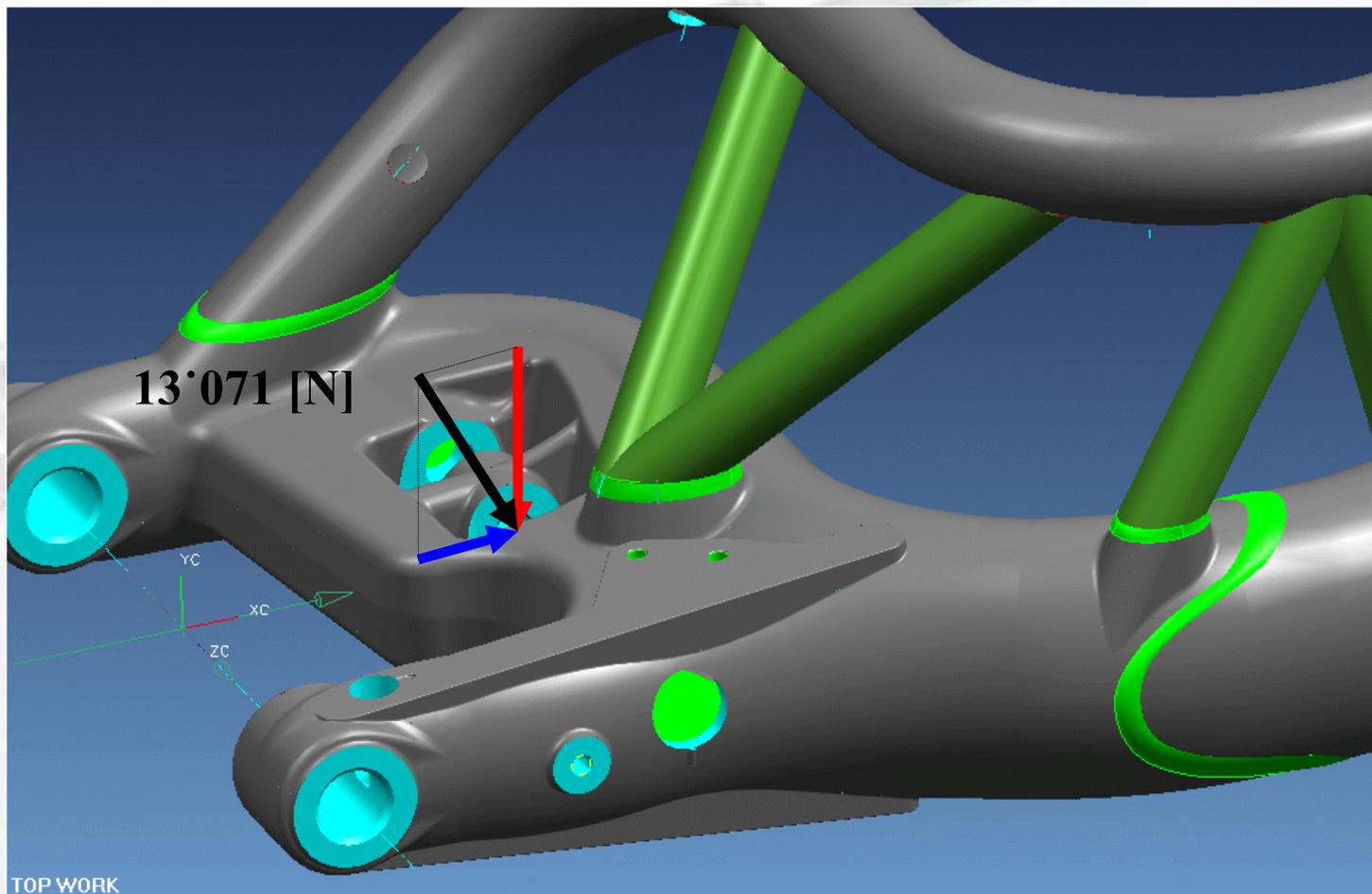
ACQUISIZIONE DEI RISULTATI

ATTRAVERSAMENTO DEL GRADINO DI 5 CM A 40 km/h

Andamento delle forze che il puntone esercita sul forcellone



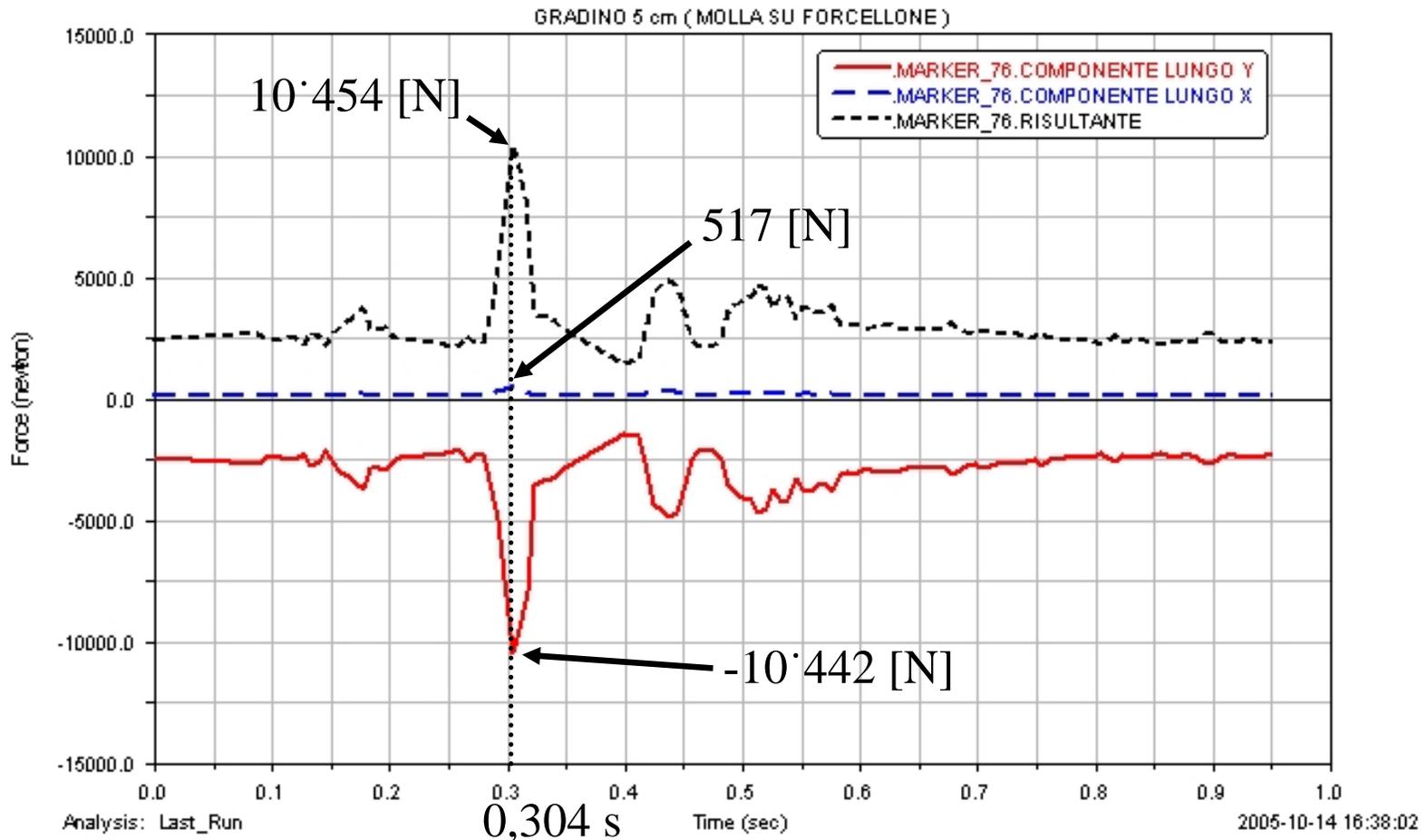
ACQUISIZIONE DEI RISULTATI



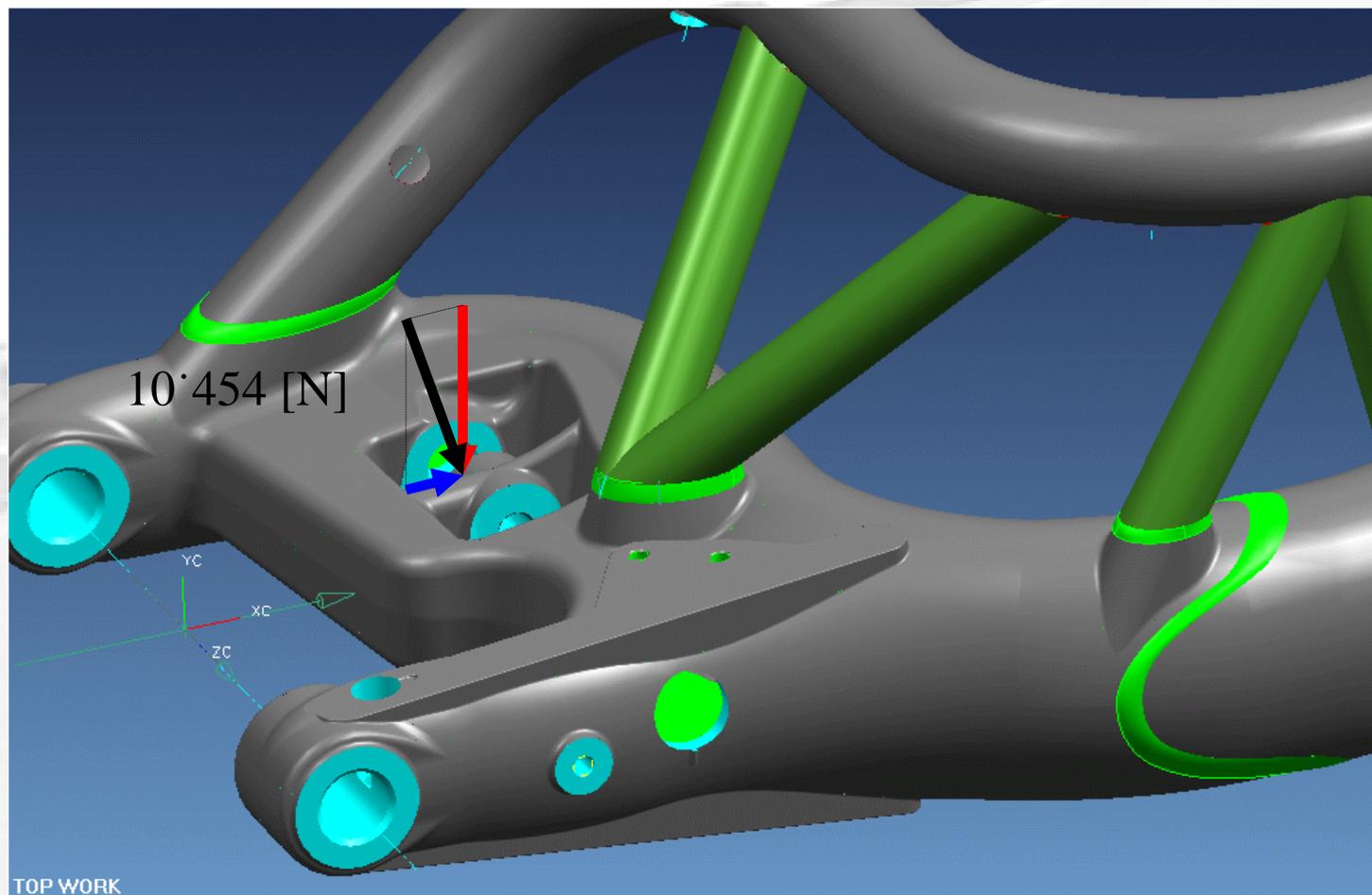
ACQUISIZIONE DEI RISULTATI

ATTRAVERSAMENTO DEL GRADINO DI 5 CM A 40 km/h

Forze che la sospensione esercita sul forcellone



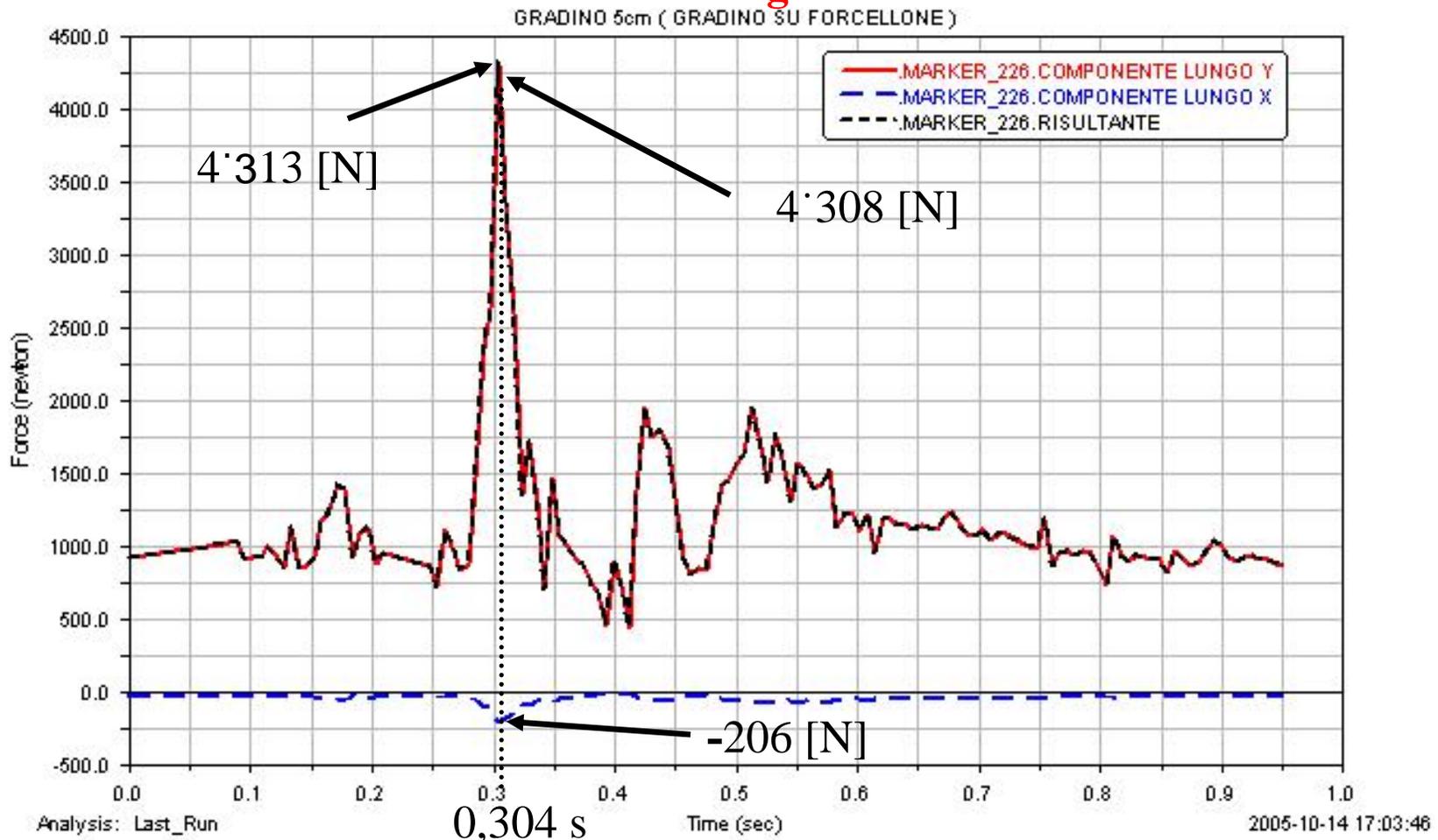
ACQUISIZIONE DEI RISULTATI



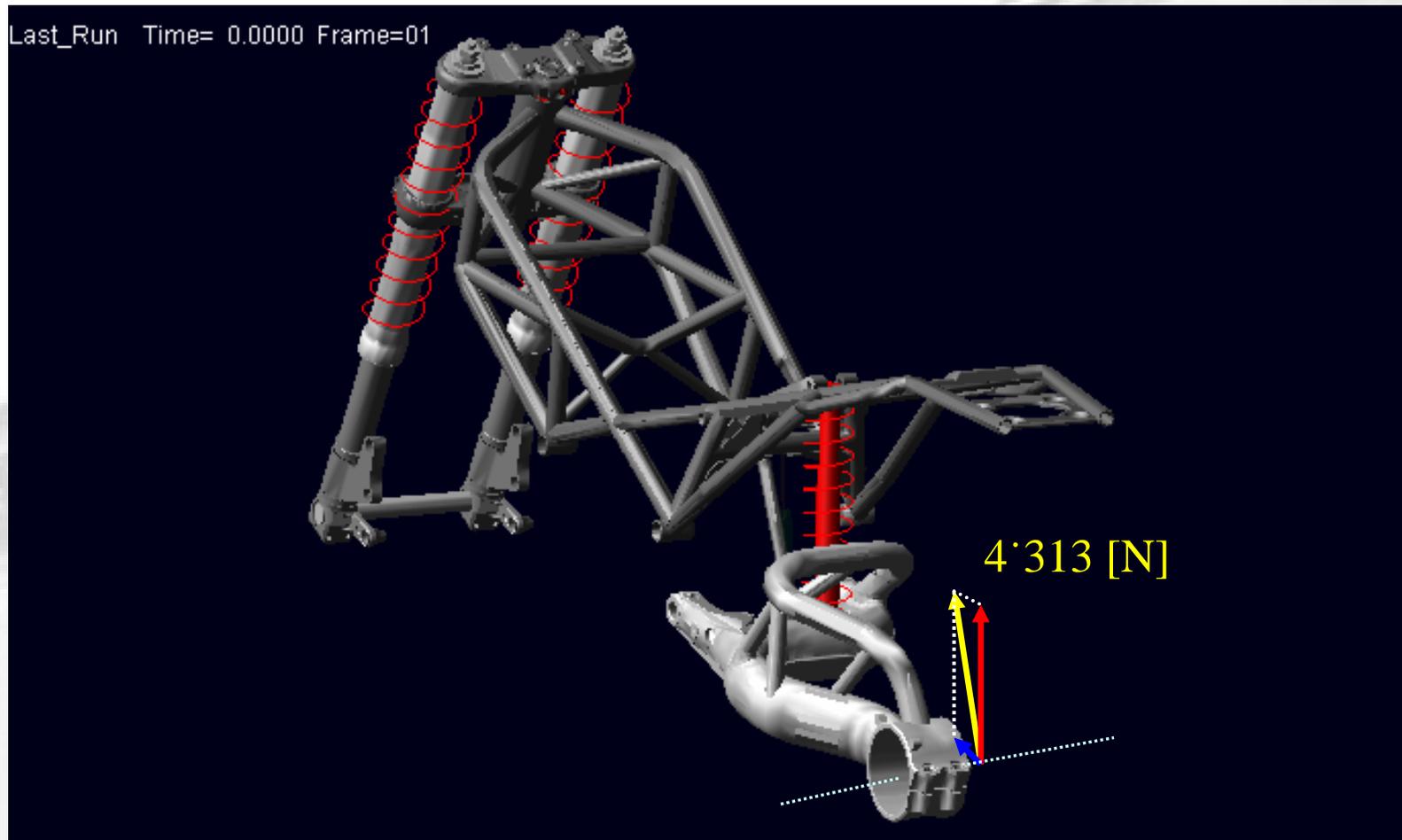
ACQUISIZIONE DEI RISULTATI

ATTRAVERSAMENTO DEL GRADINO DI 5 CM A 40 km/h

Andamento delle reazioni che il gradino esercita sul forcellone



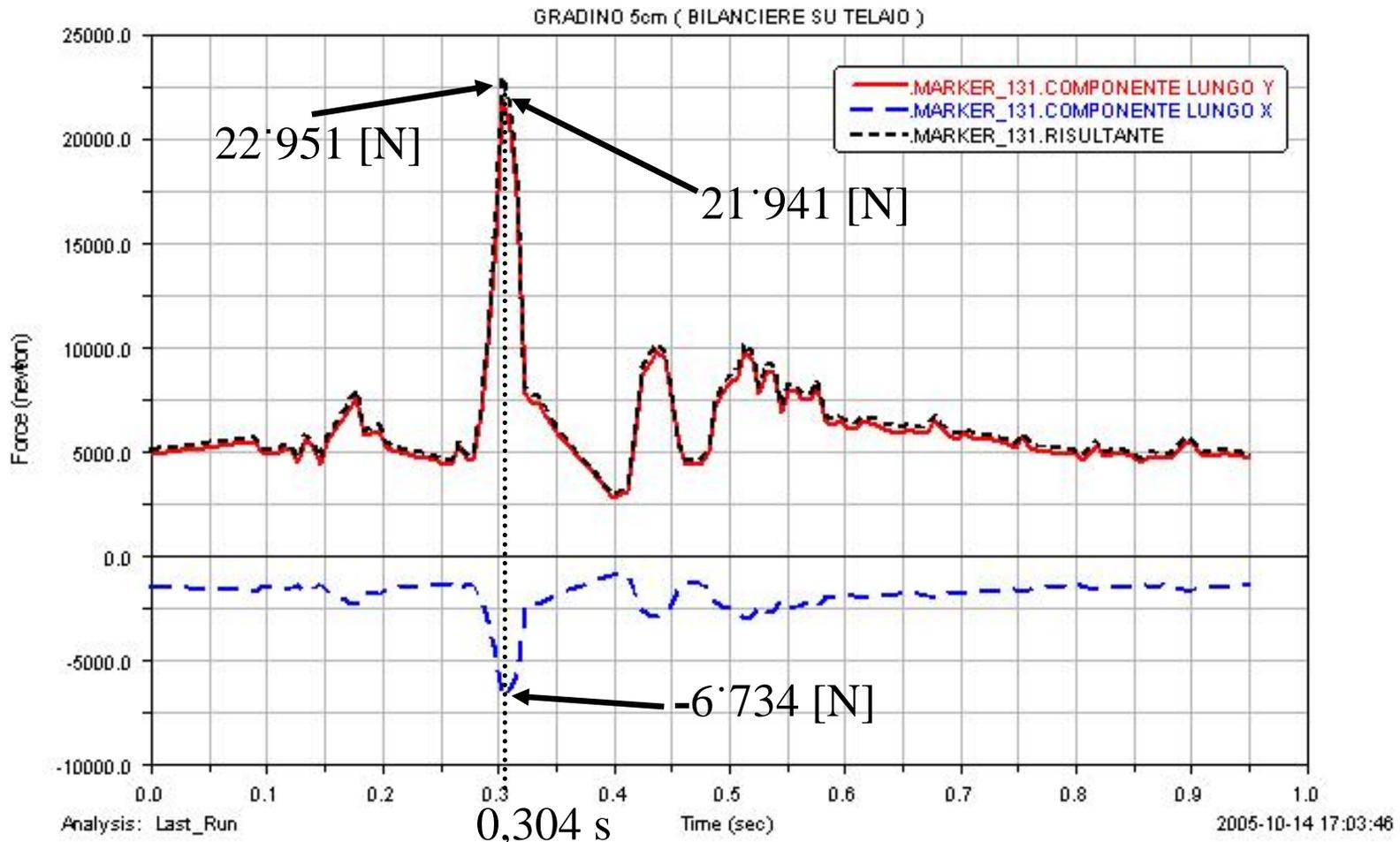
ACQUISIZIONE DEI RISULTATI



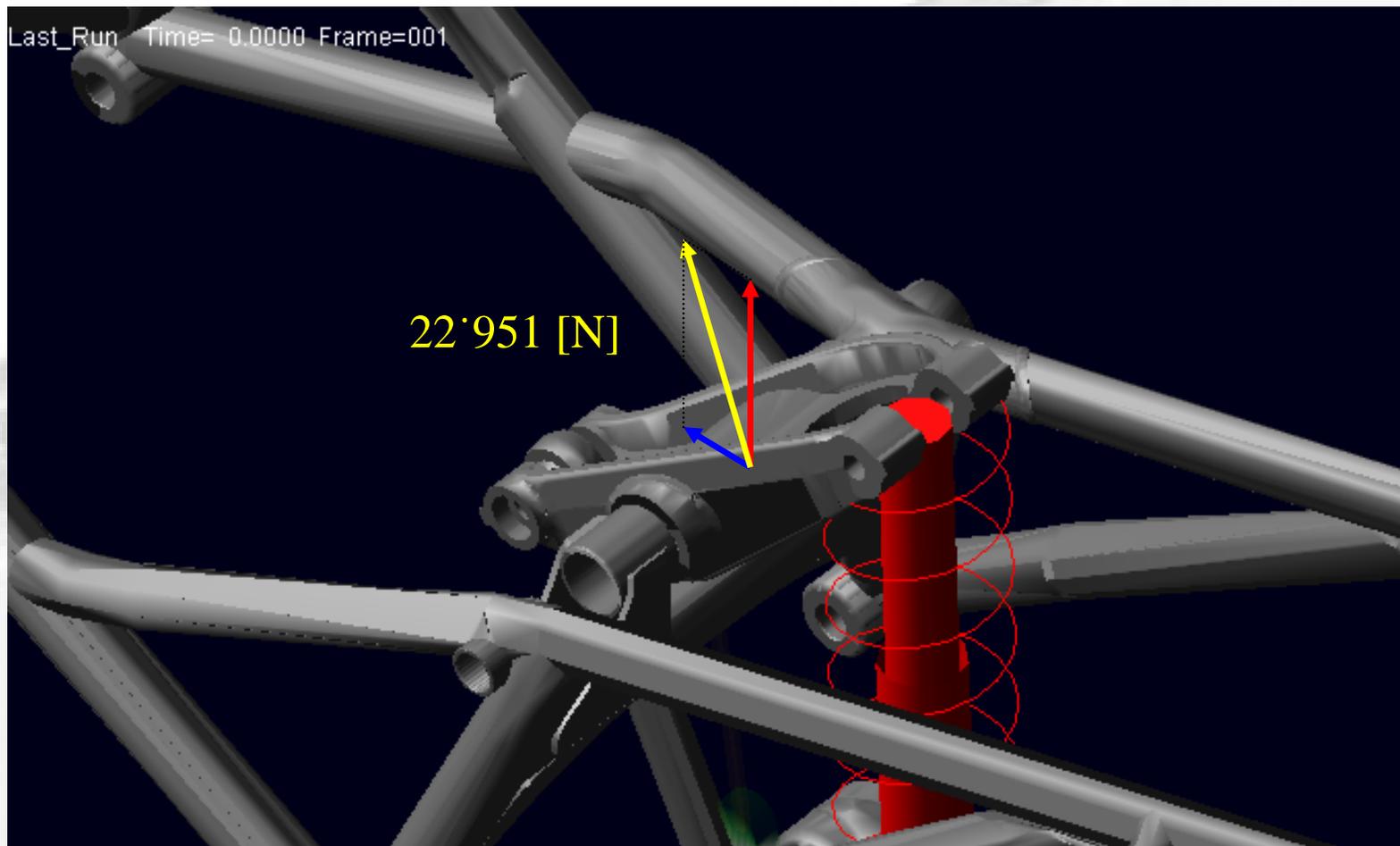
ACQUISIZIONE DEI RISULTATI

ATTRAVERSAMENTO DEL GRADINO DI 5 CM A 40 km/h

Andamento delle forze che il bilanciere esercita sul telaio



ACQUISIZIONE DEI RISULTATI

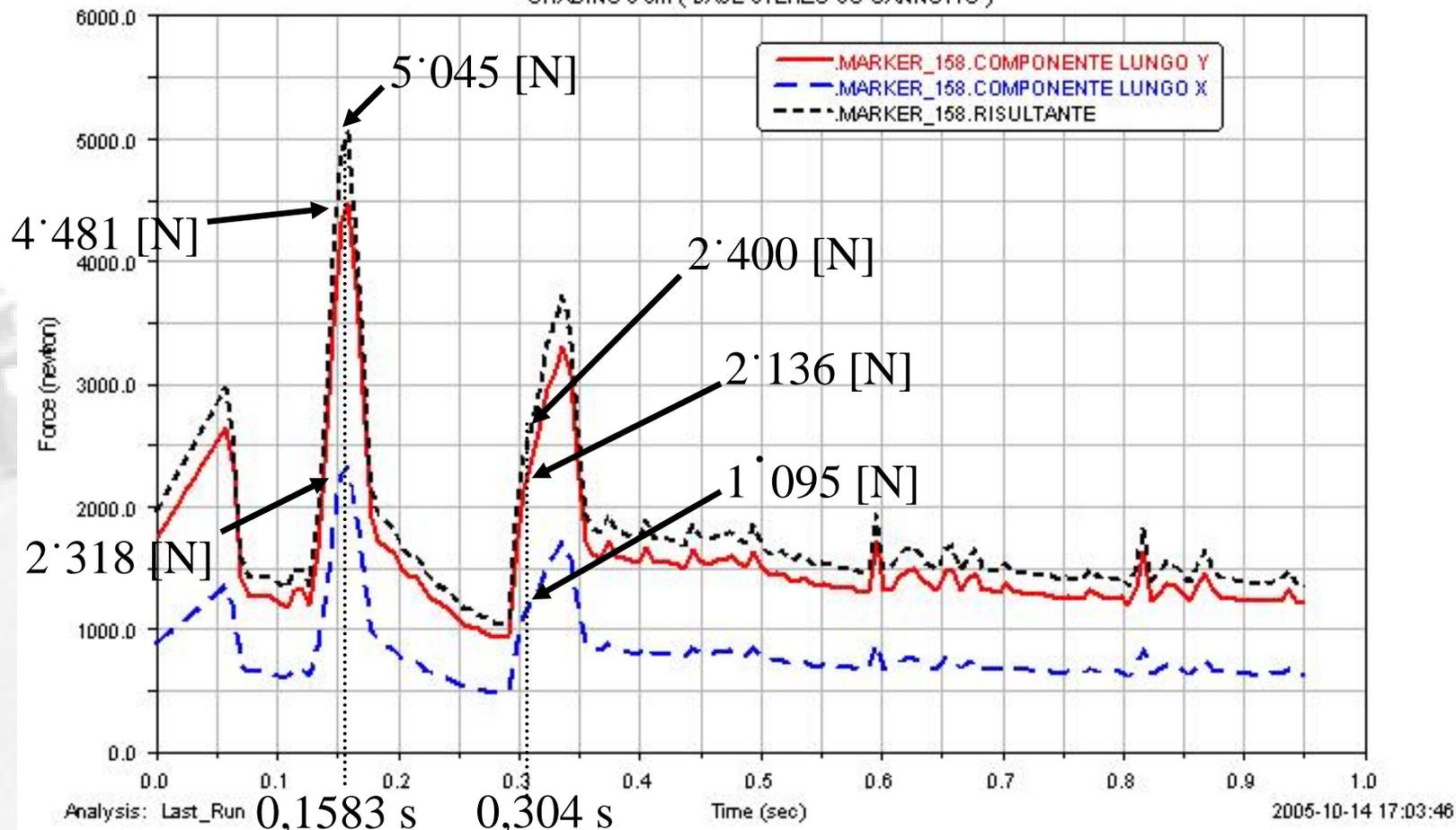


ACQUISIZIONE DEI RISULTATI

ATTRAVERSAMENTO DEL GRADINO DI 5 CM A 40 km/h

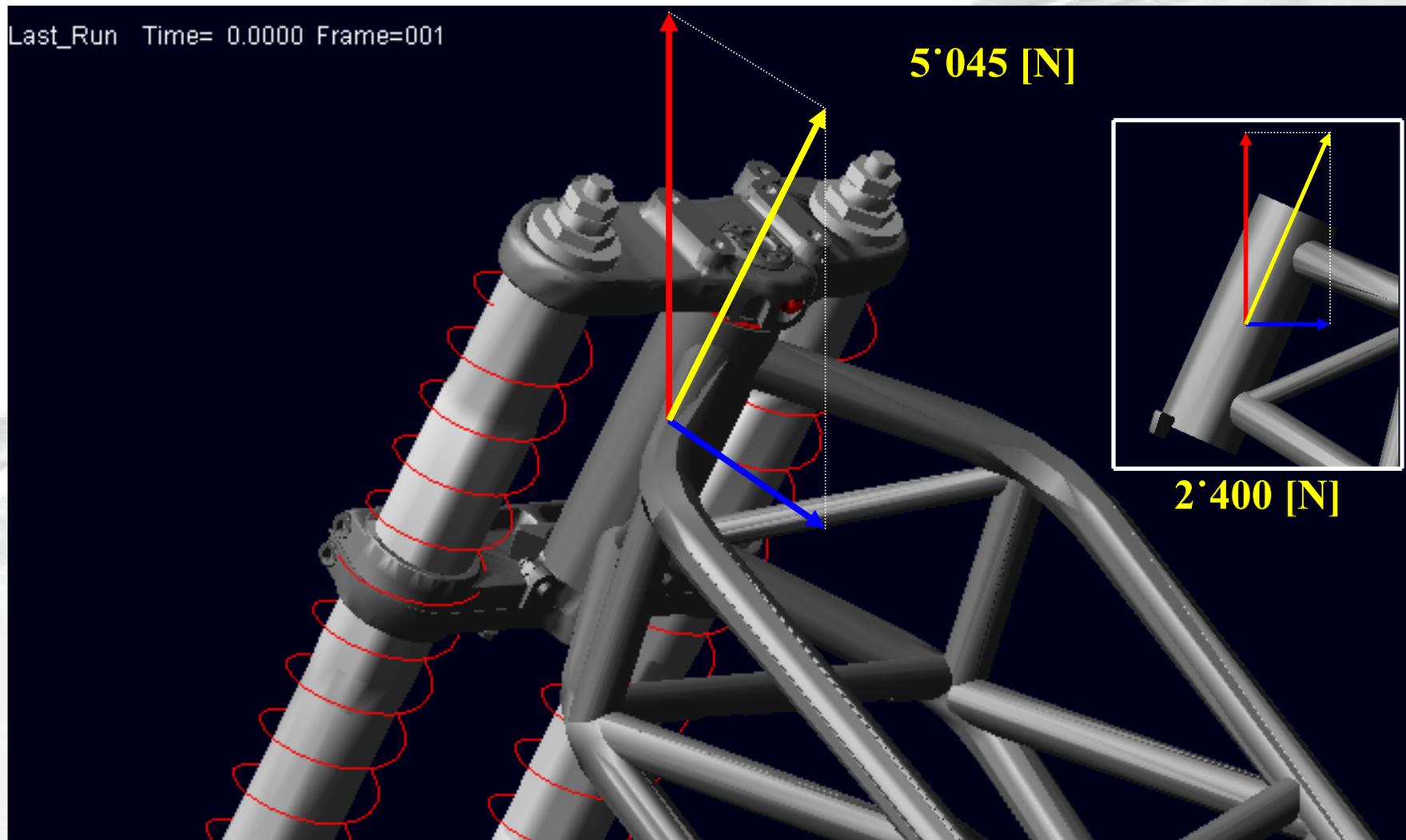
Andamento delle forze che la forcella anteriore esercita sul telaio

GRADINO 5 cm (BASE STERZO SU CANNOTTO)



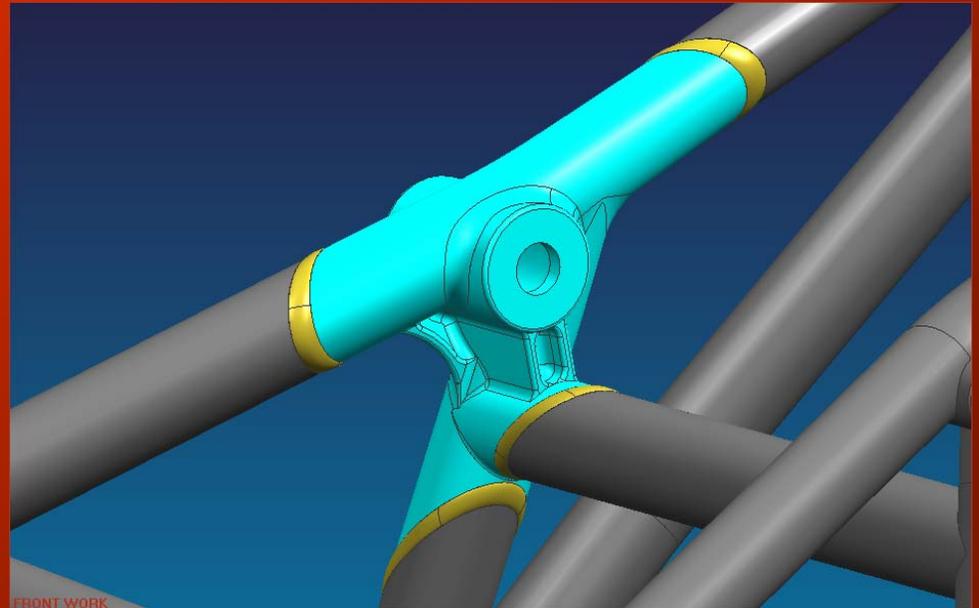
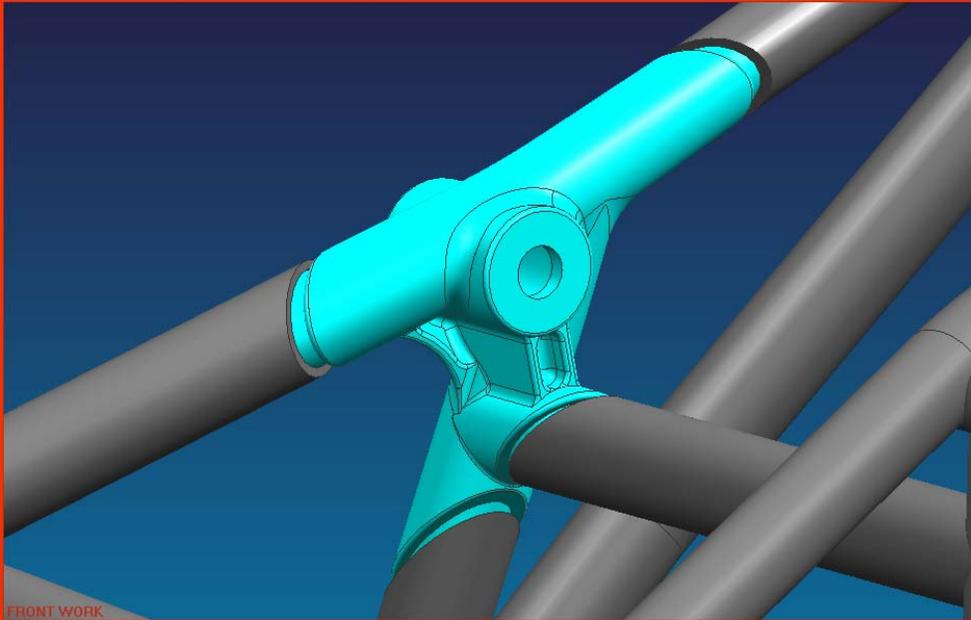
ACQUISIZIONE DEI RISULTATI

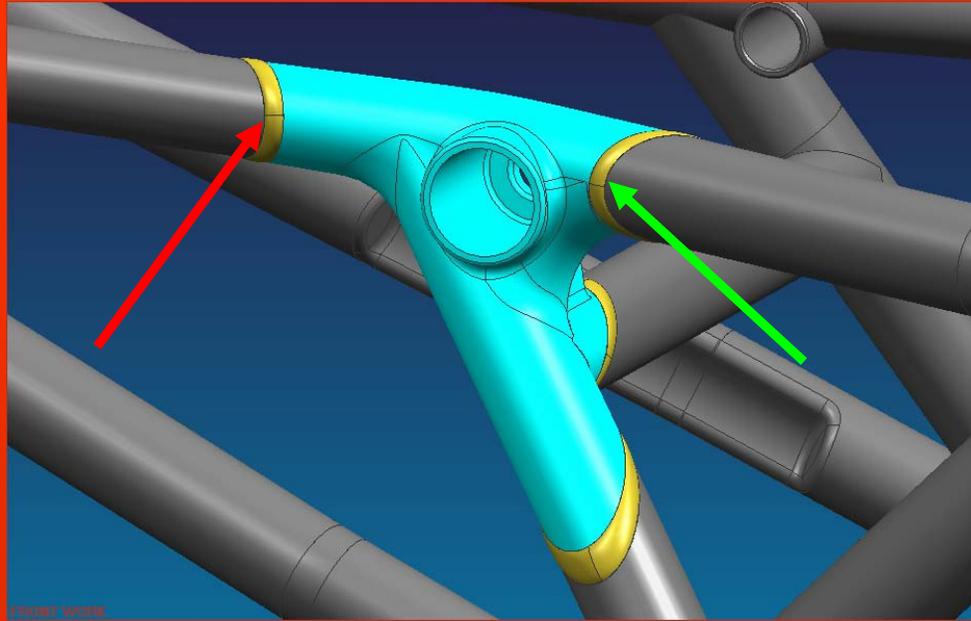
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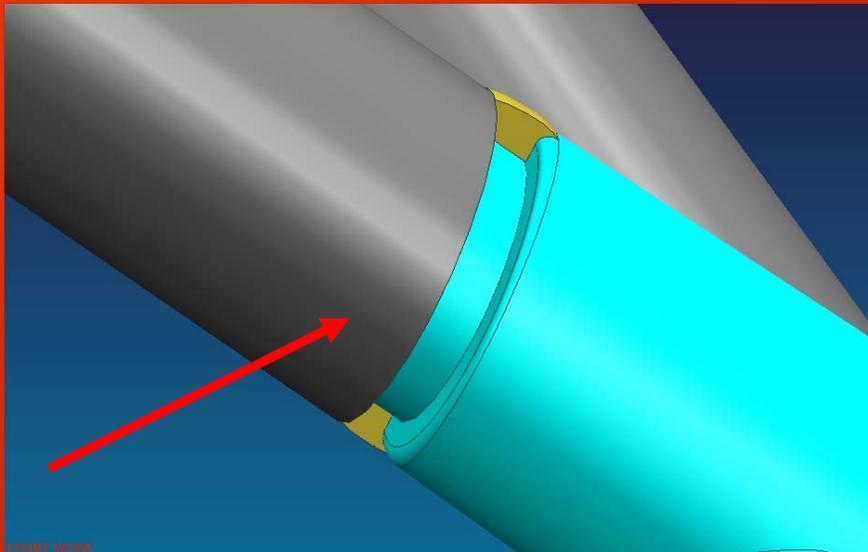


**COSTRUZIONE DEL
MODELLO GEOMETRICO
VIRTUALE**

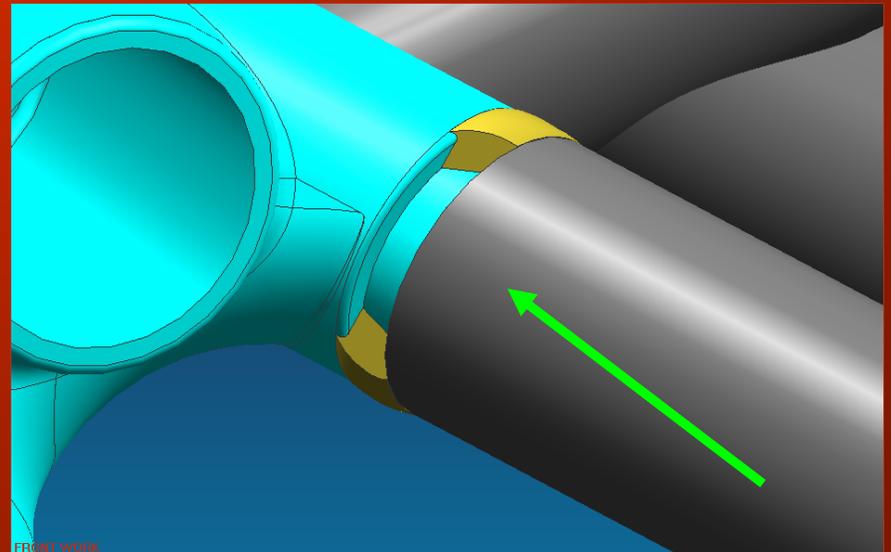




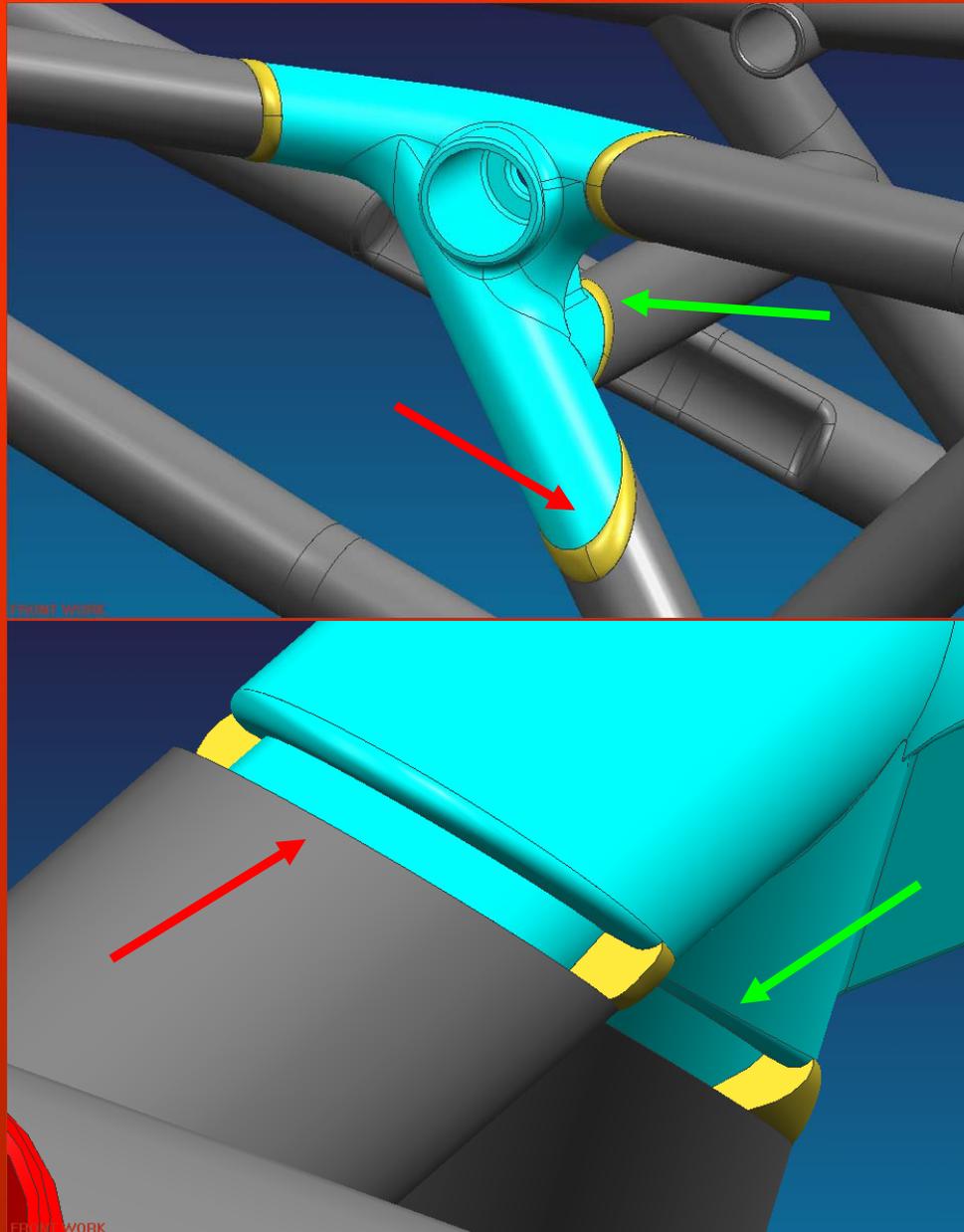
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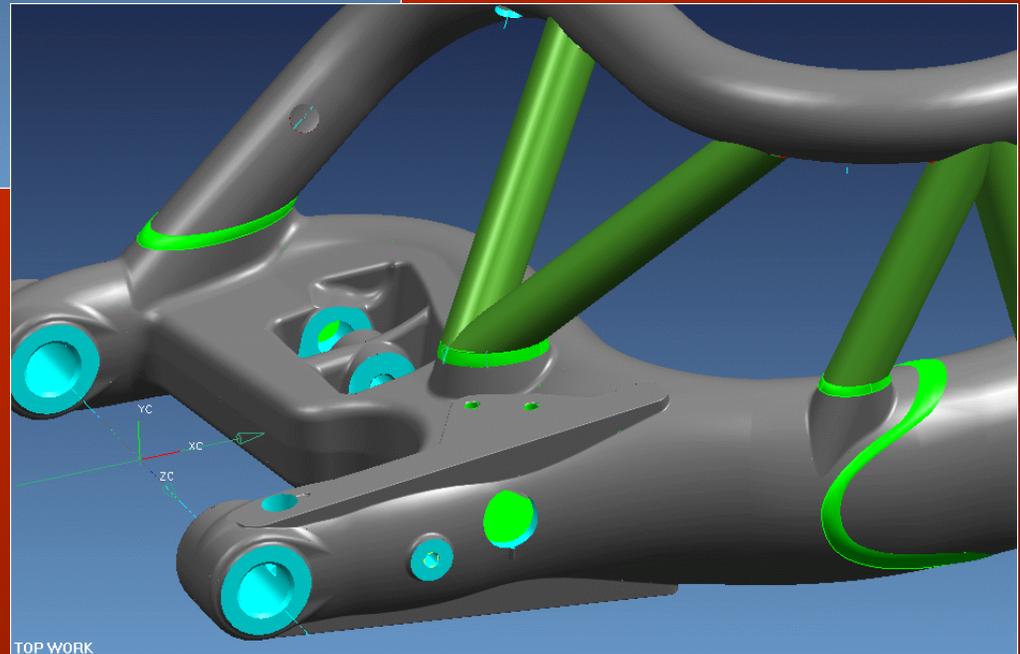
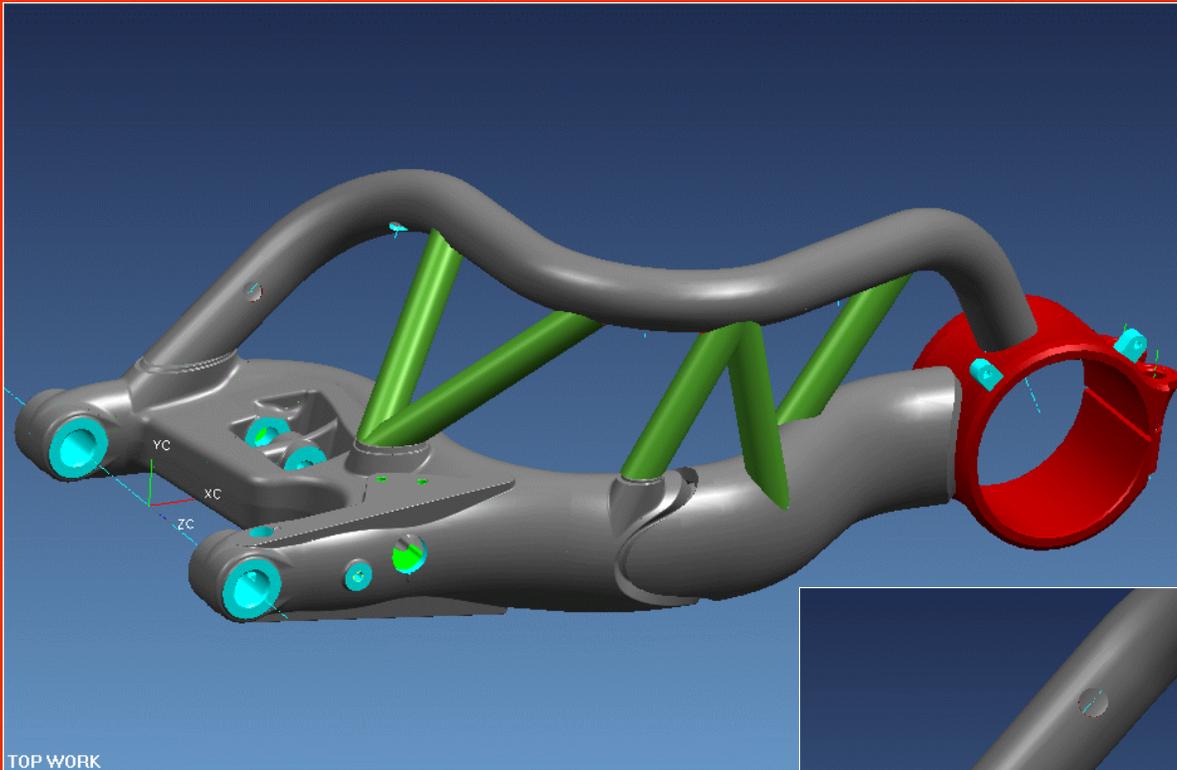


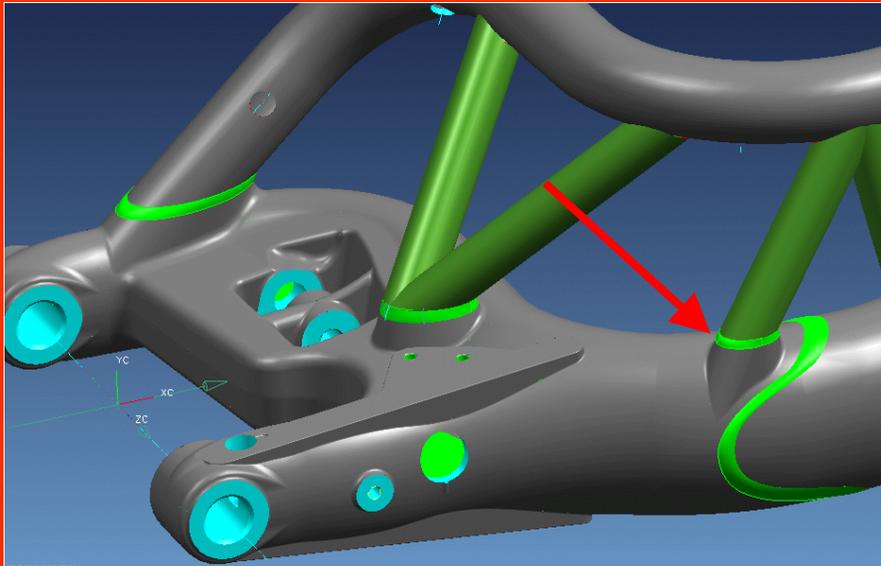
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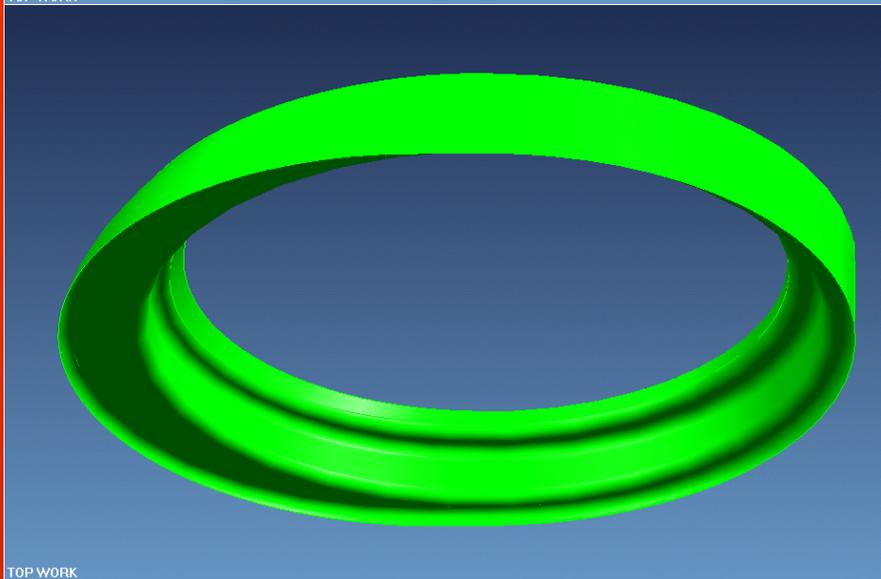
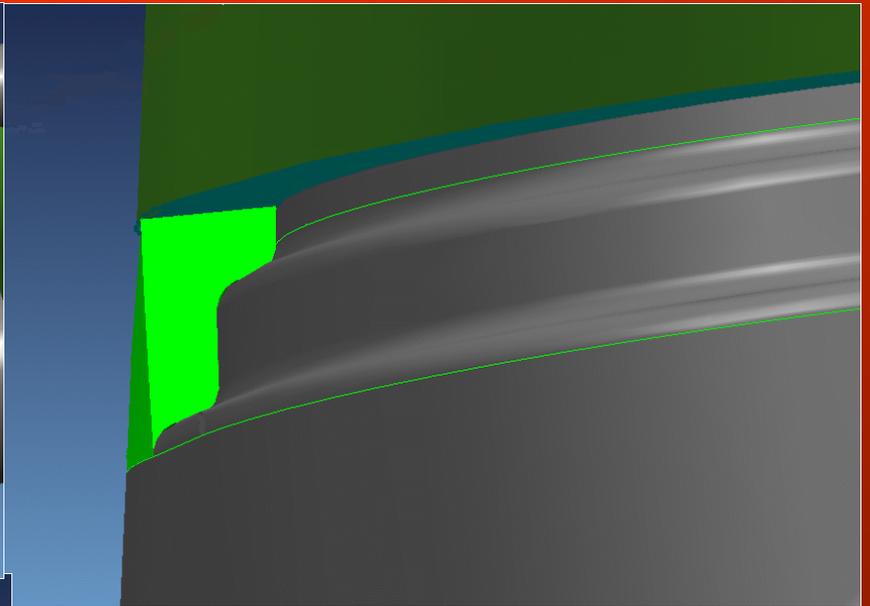
FRONT VIEW



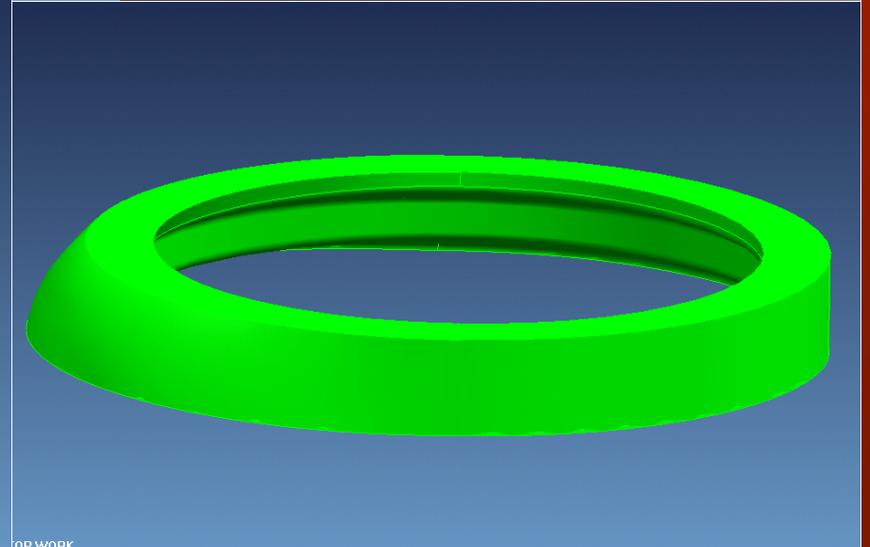




TOP WORK

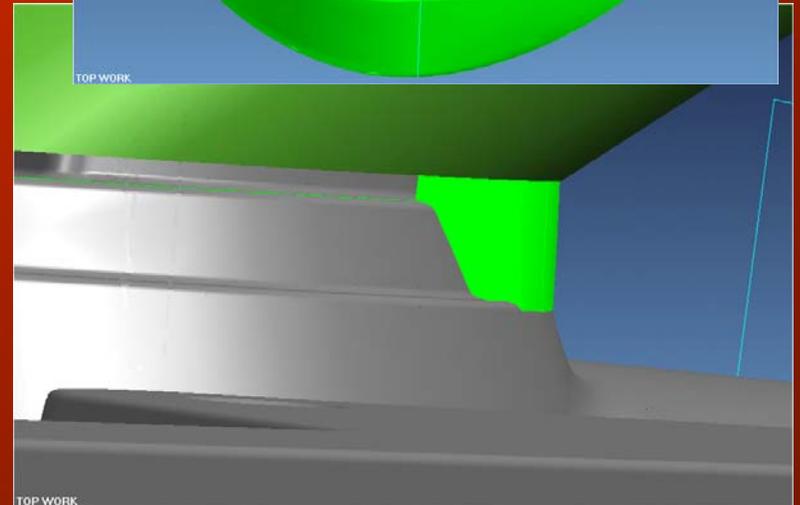
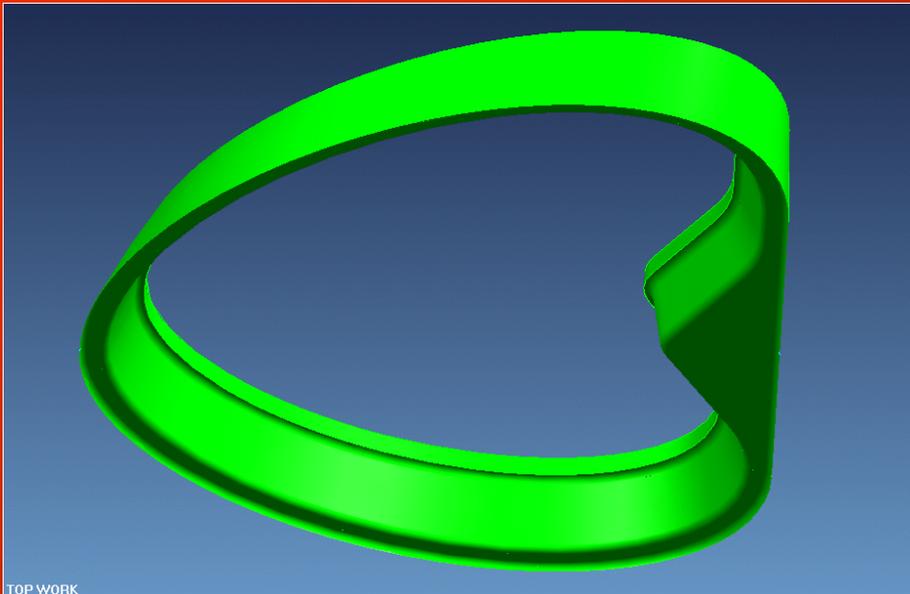
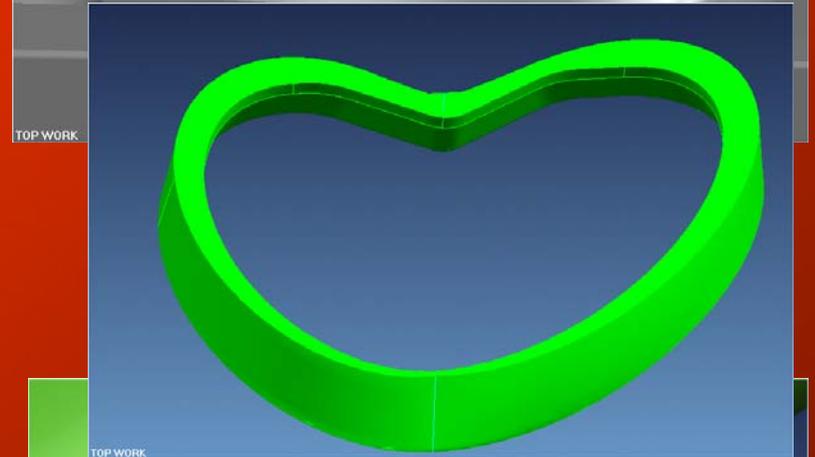
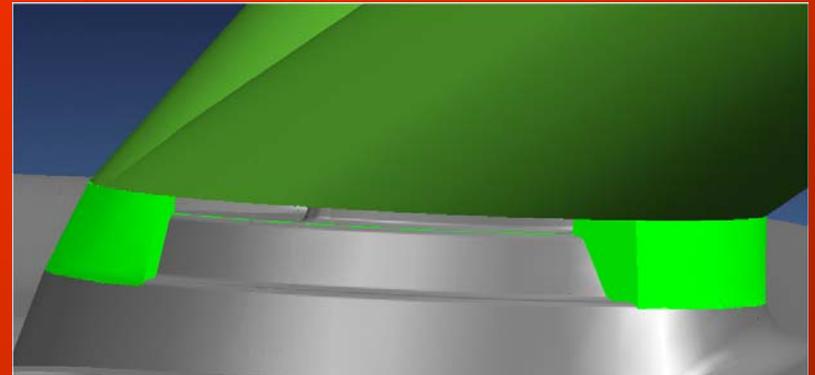
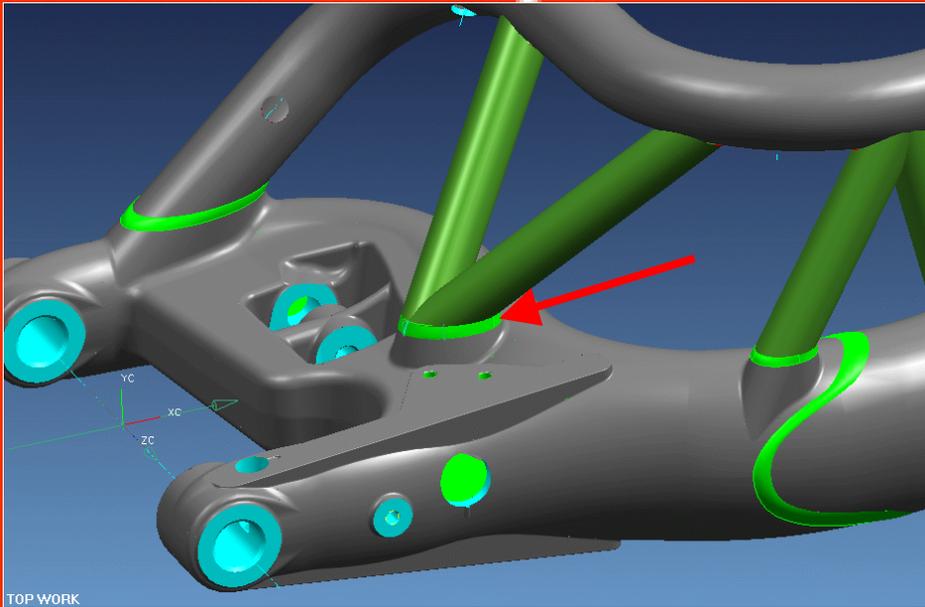


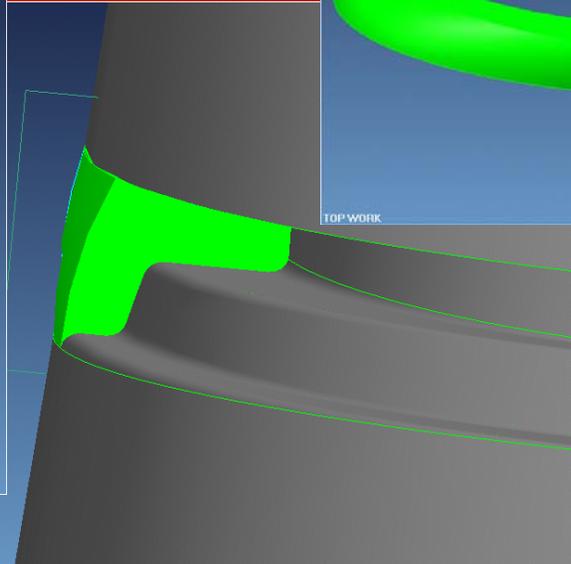
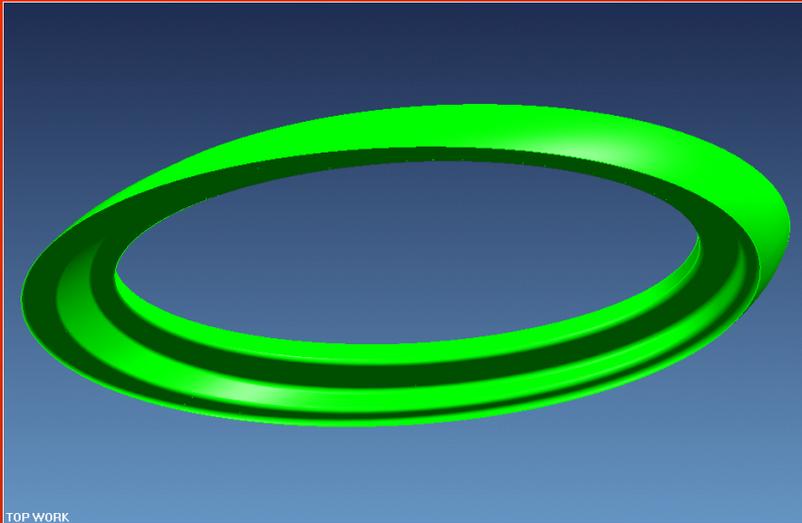
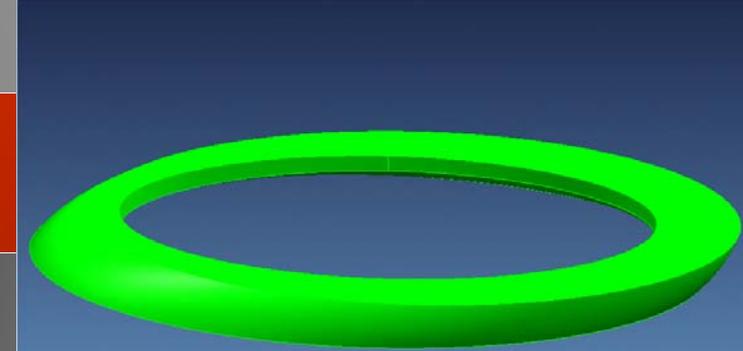
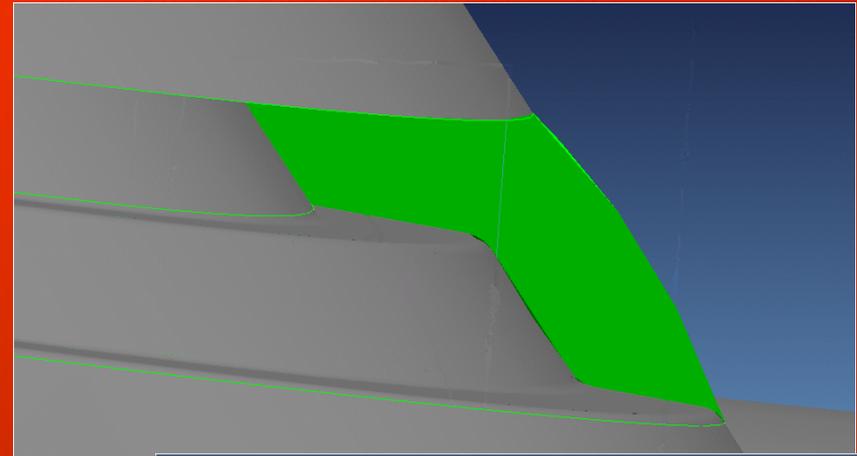
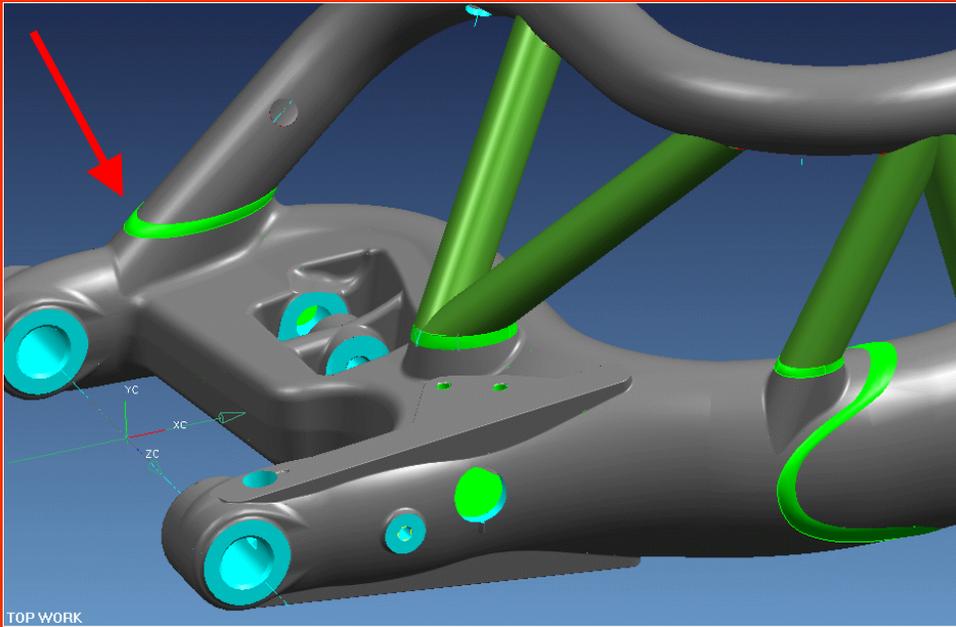
TOP WORK

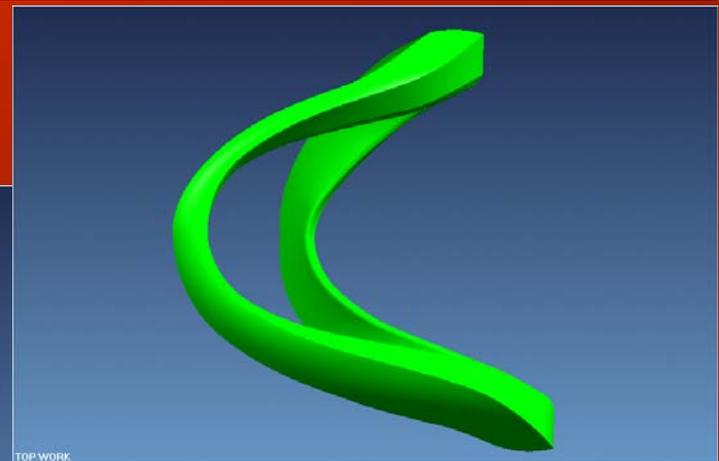
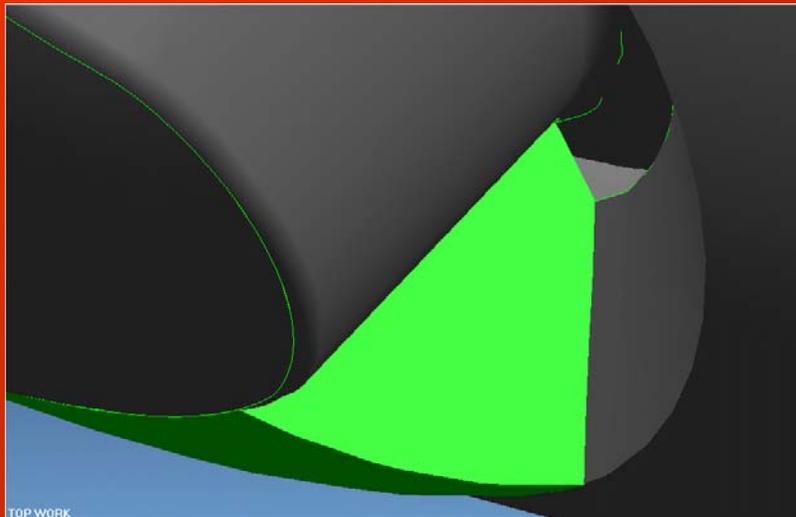
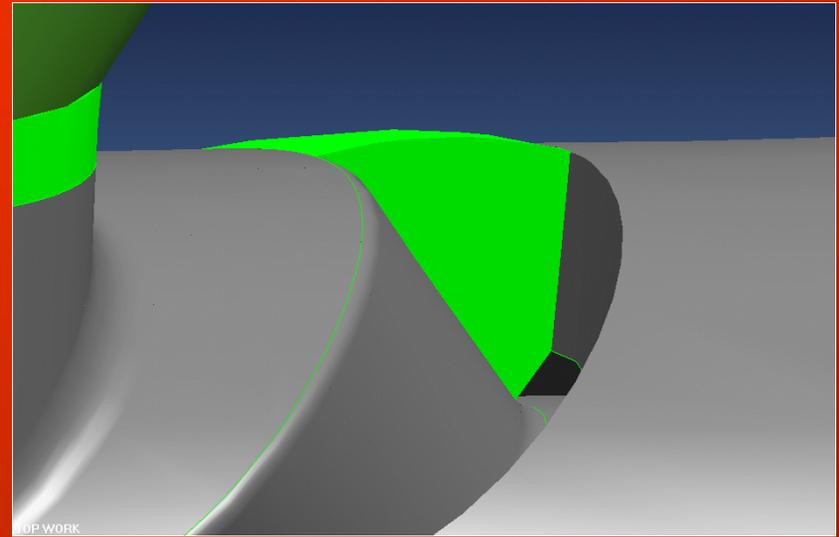
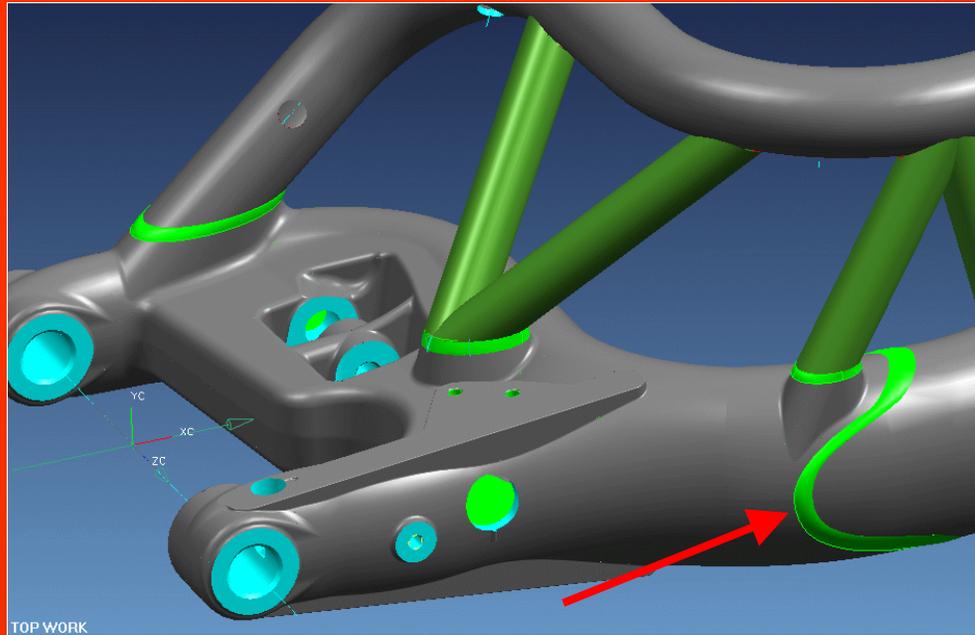


TOP WORK





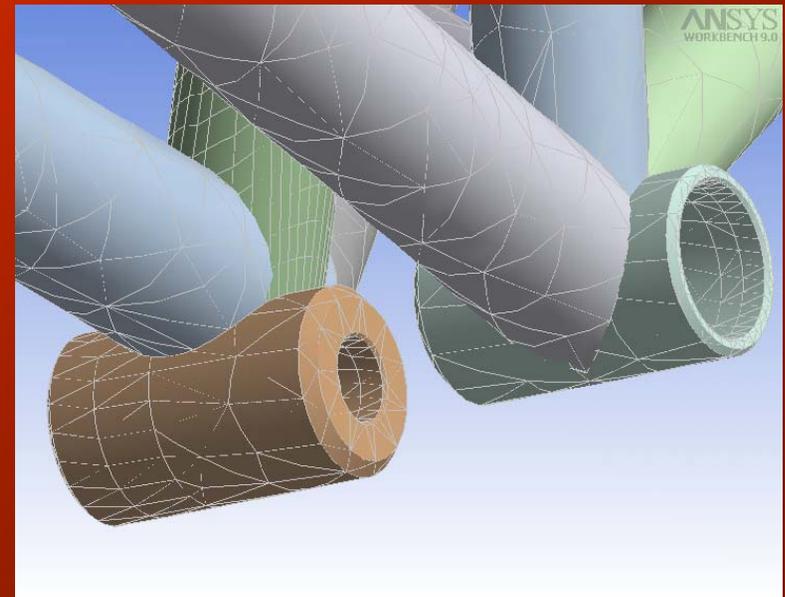
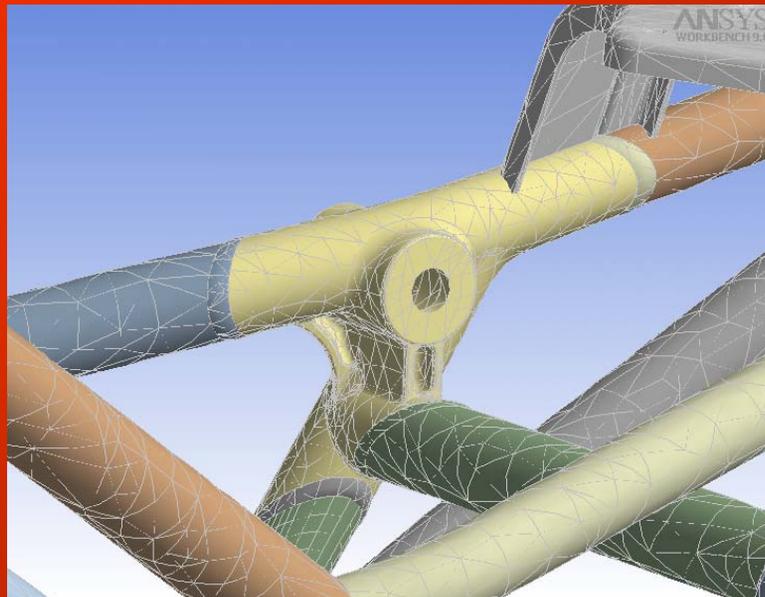
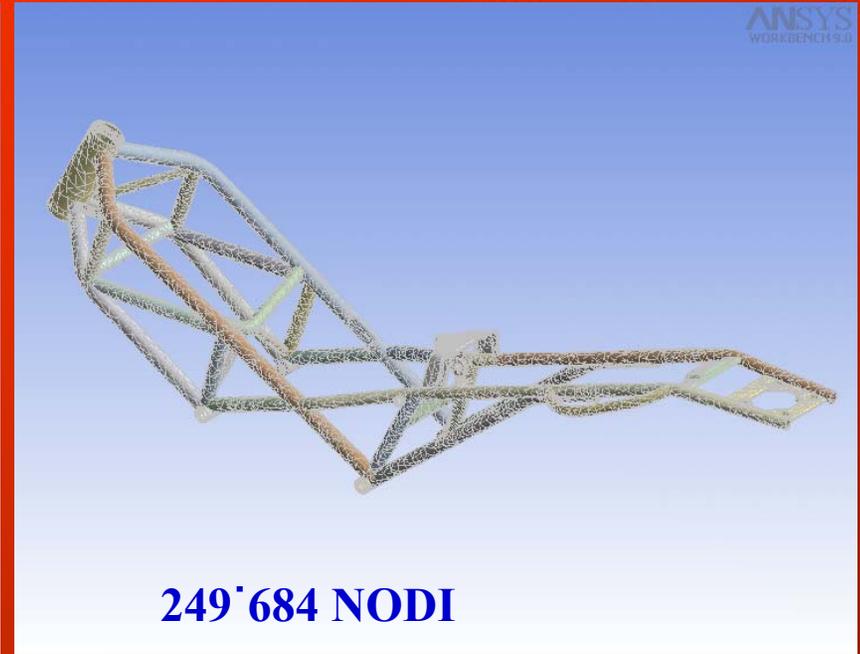






LE VERIFICHE DI RESISTENZA





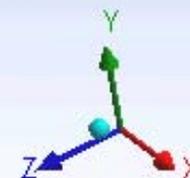
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Vincolo fisso

Carico a perno: 11475.1 N

Carico a perno 2: 11475.1 N

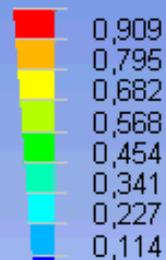
0.000 0.156 0.311 0.467 (m)



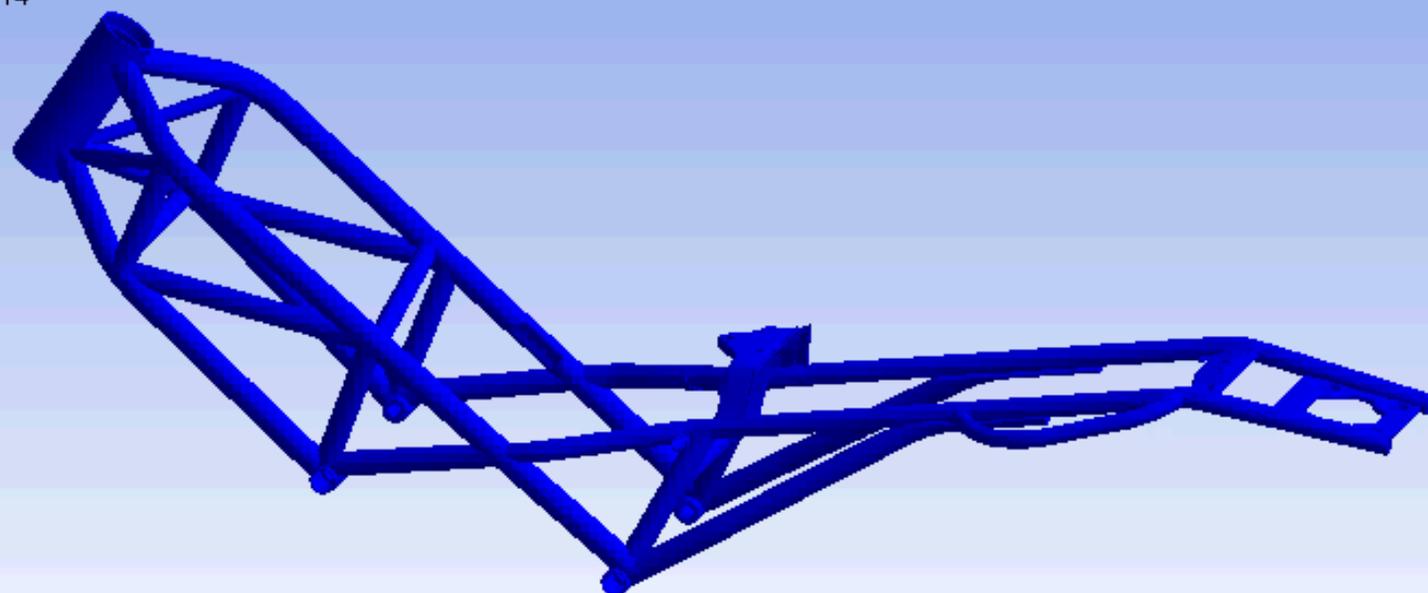
Sollecitazione equivalente (von Mises)

X 1e9 Pa

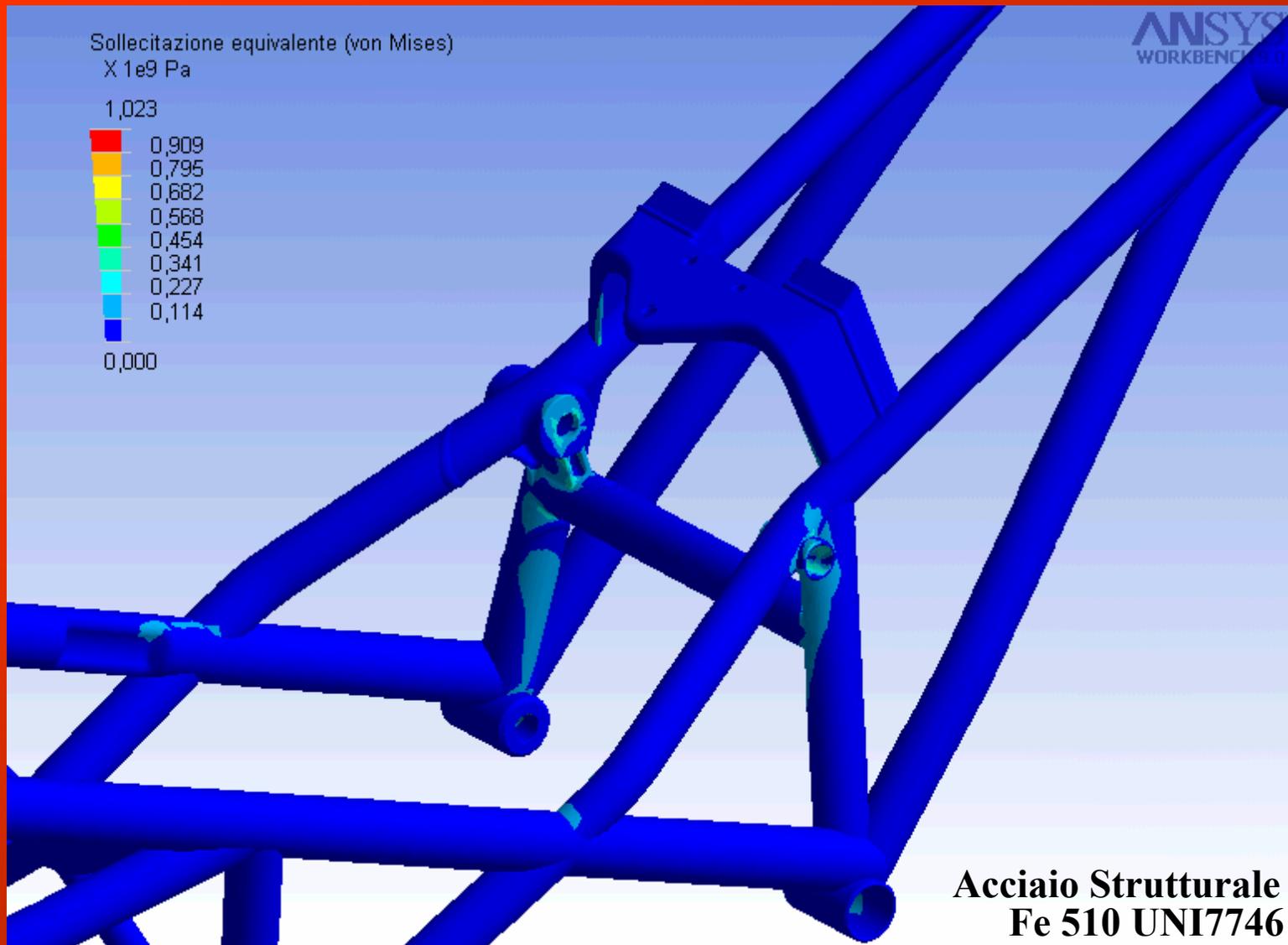
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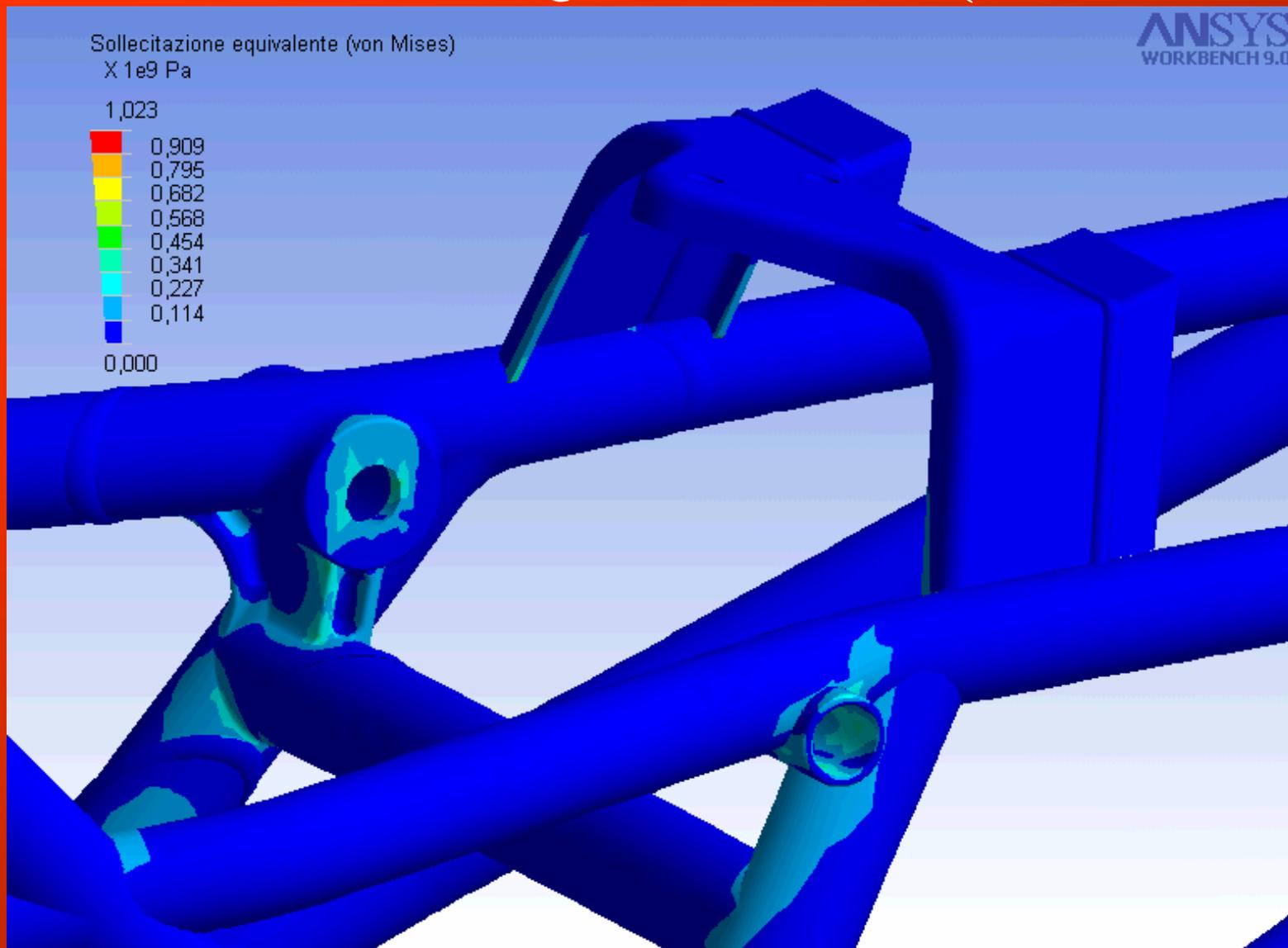
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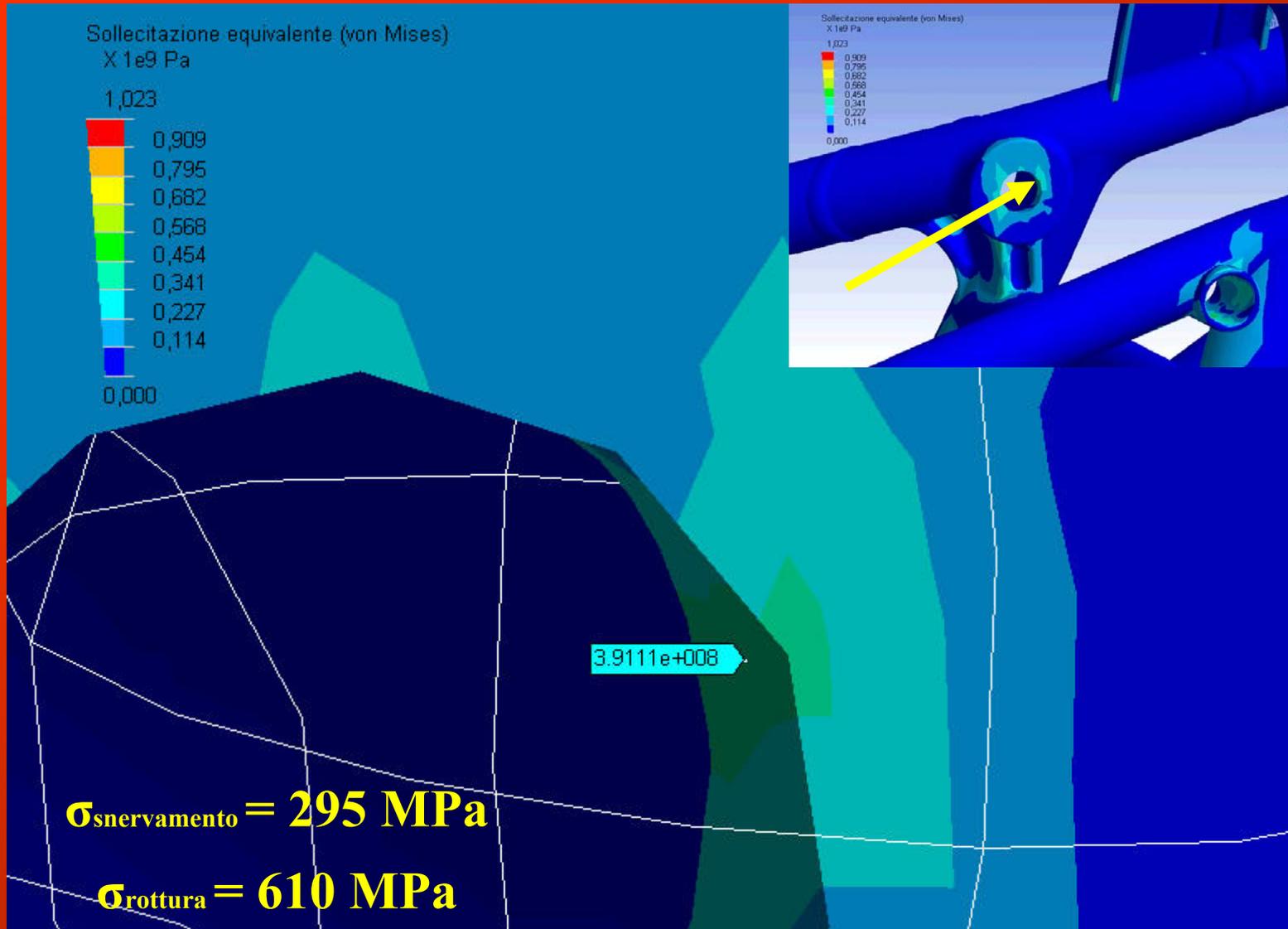
SOLLECITAZIONE EQUIVALENTE (VON MISES)



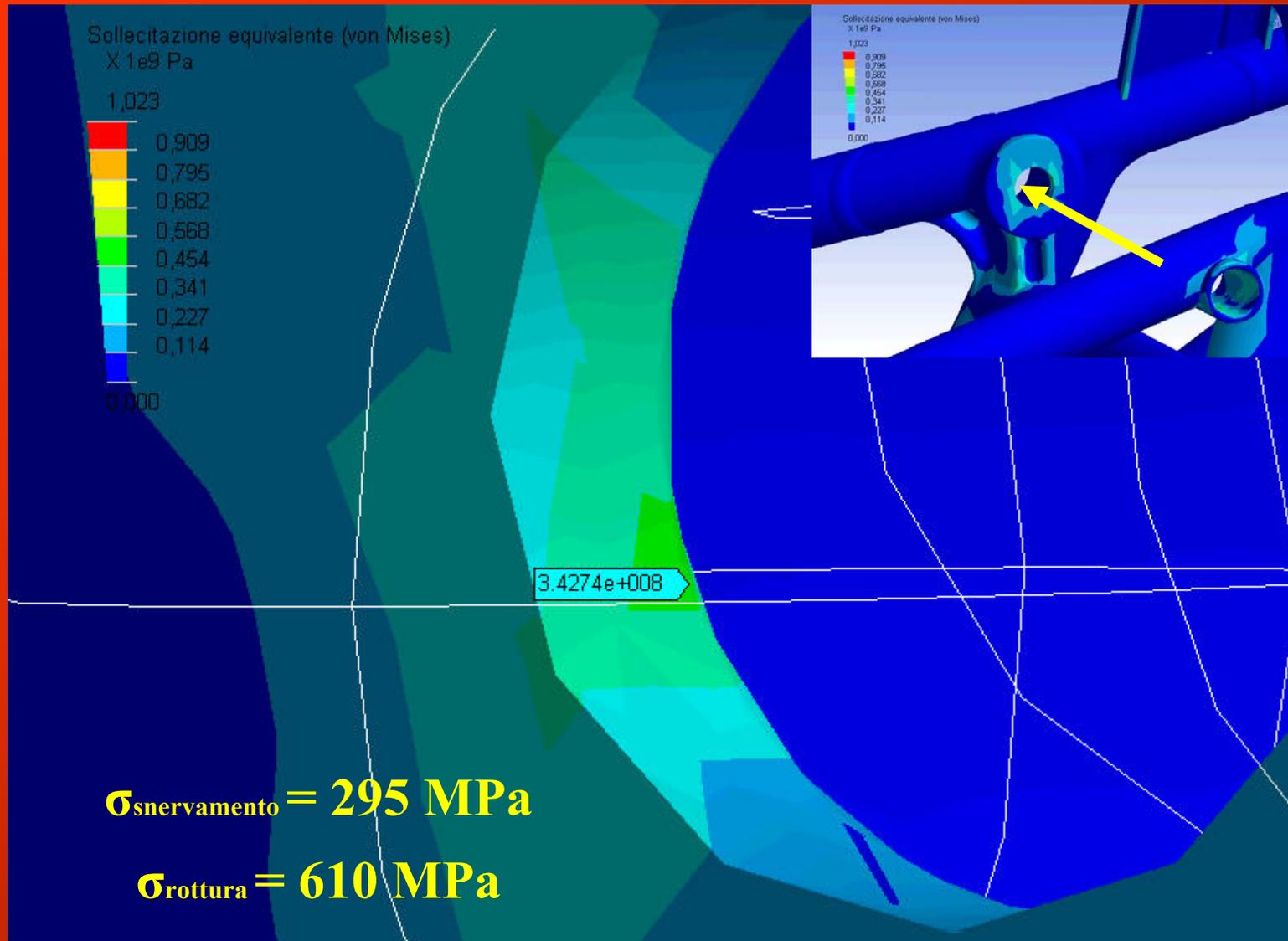
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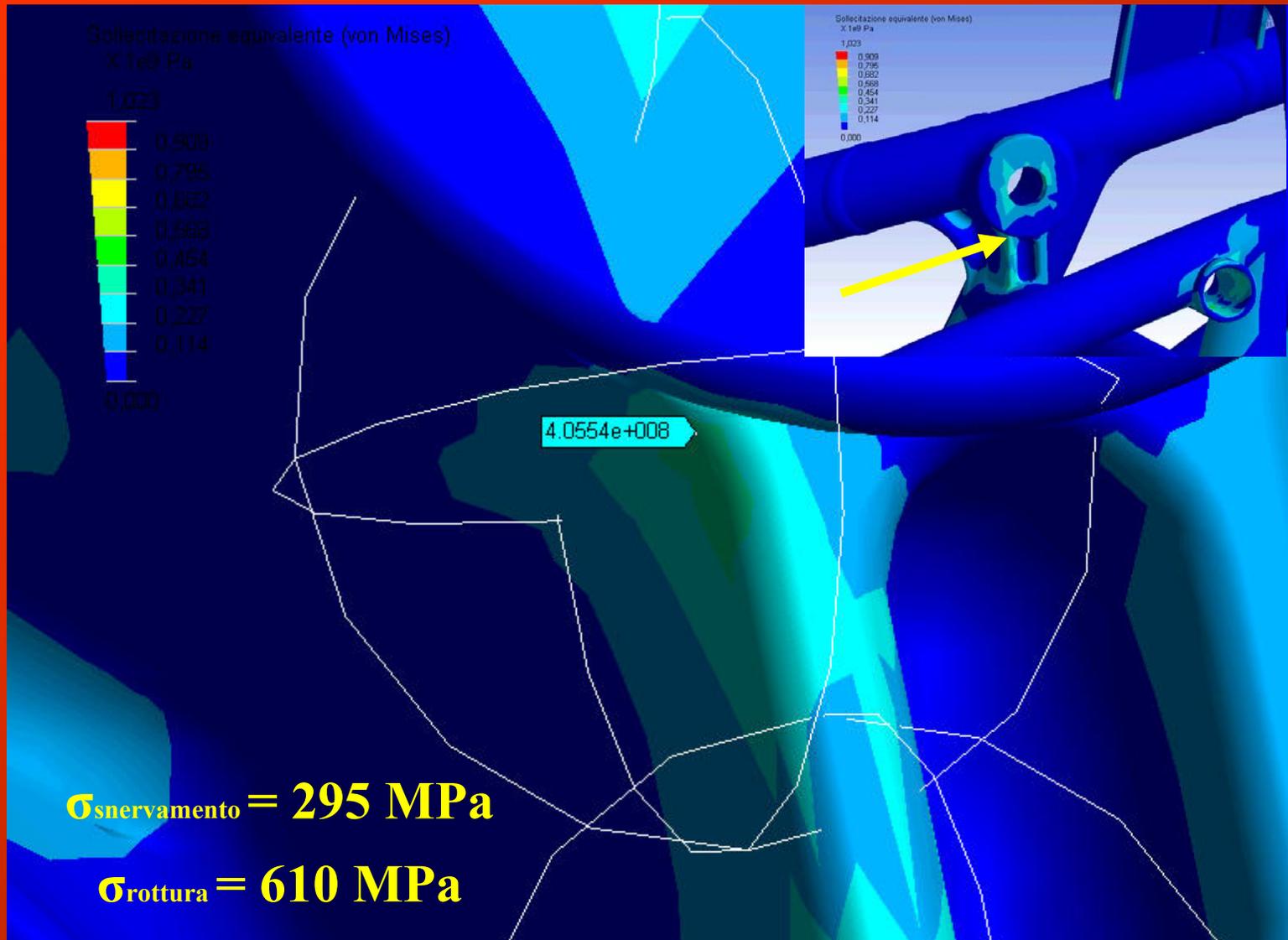
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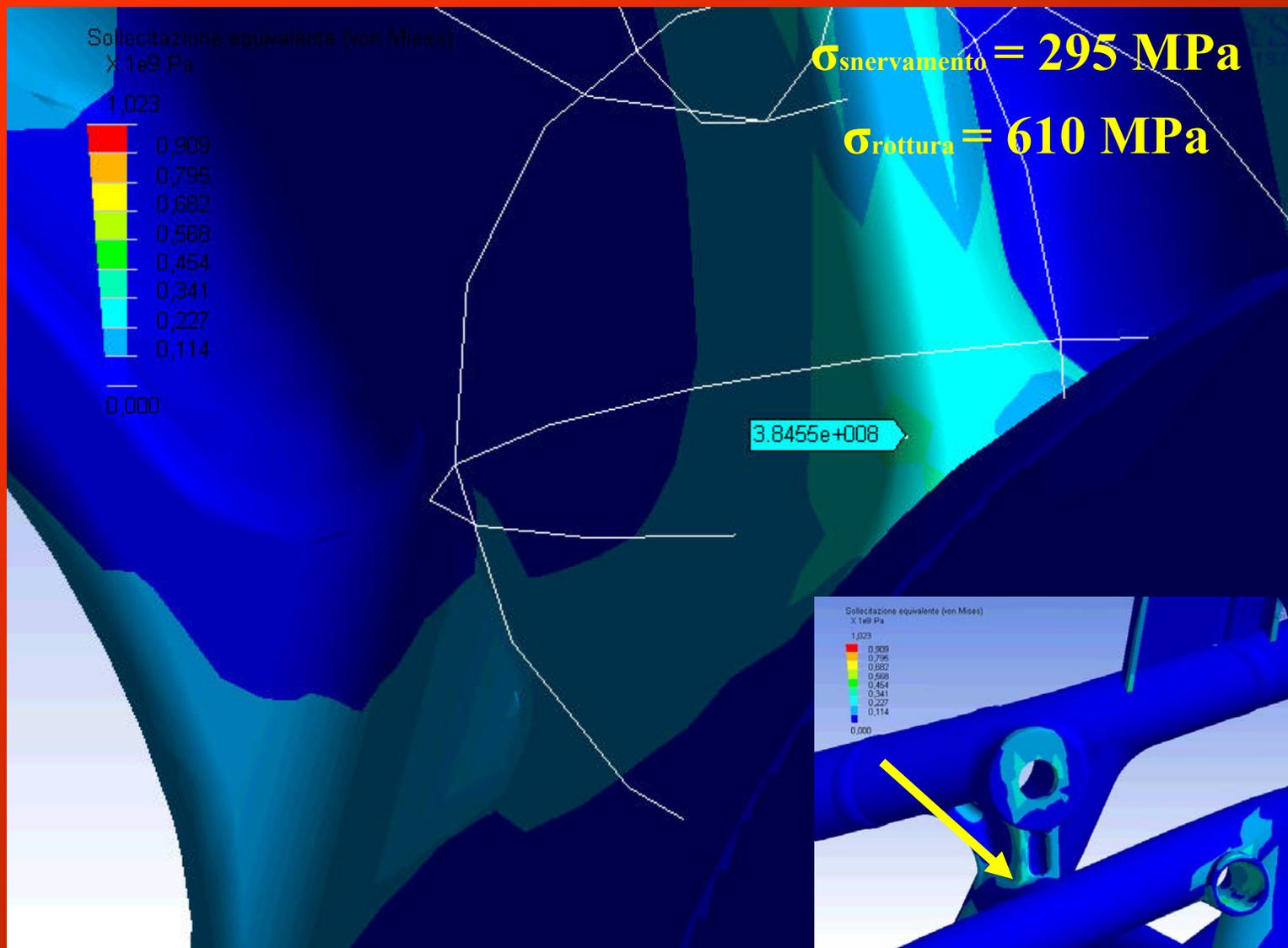
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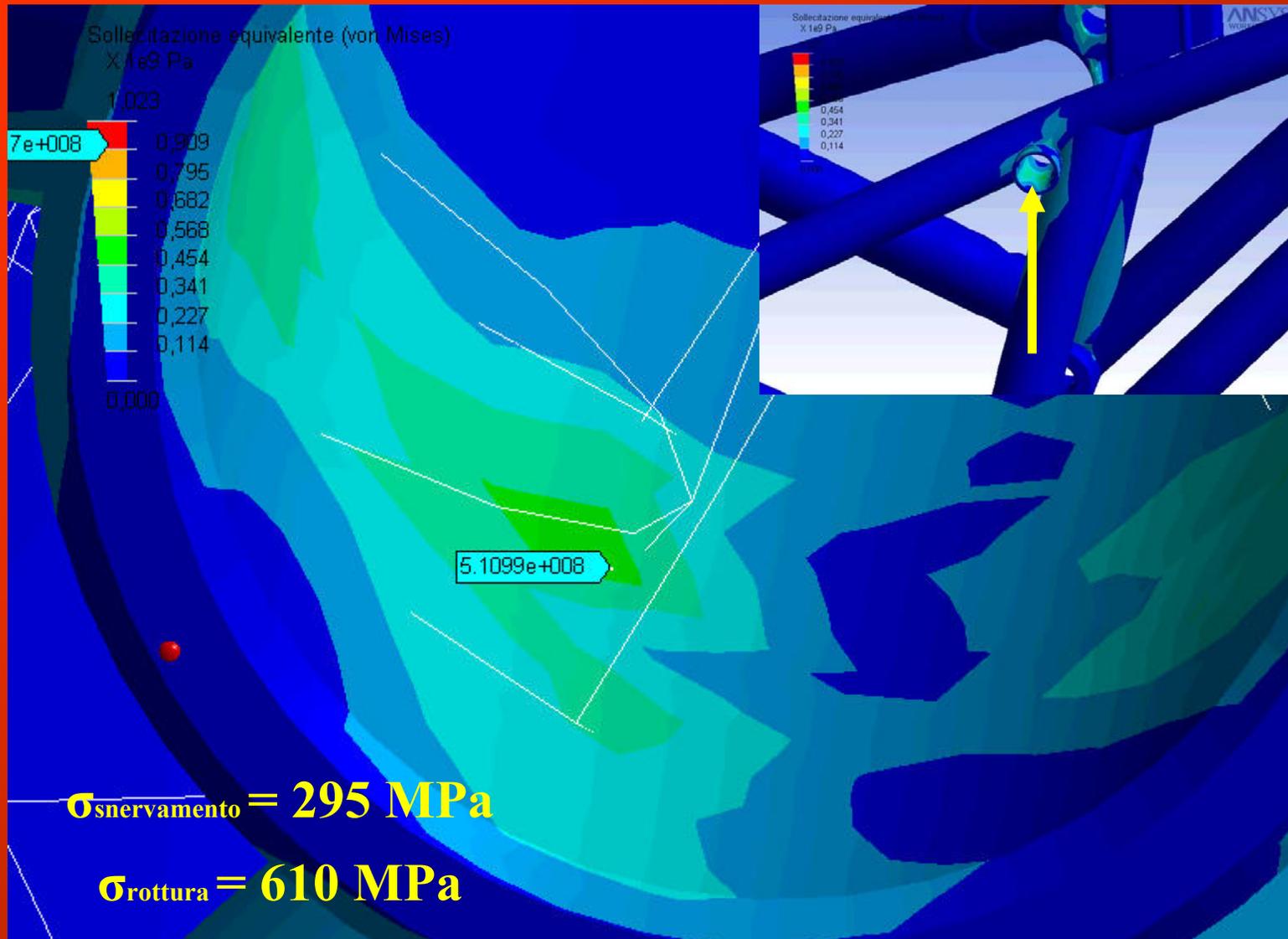
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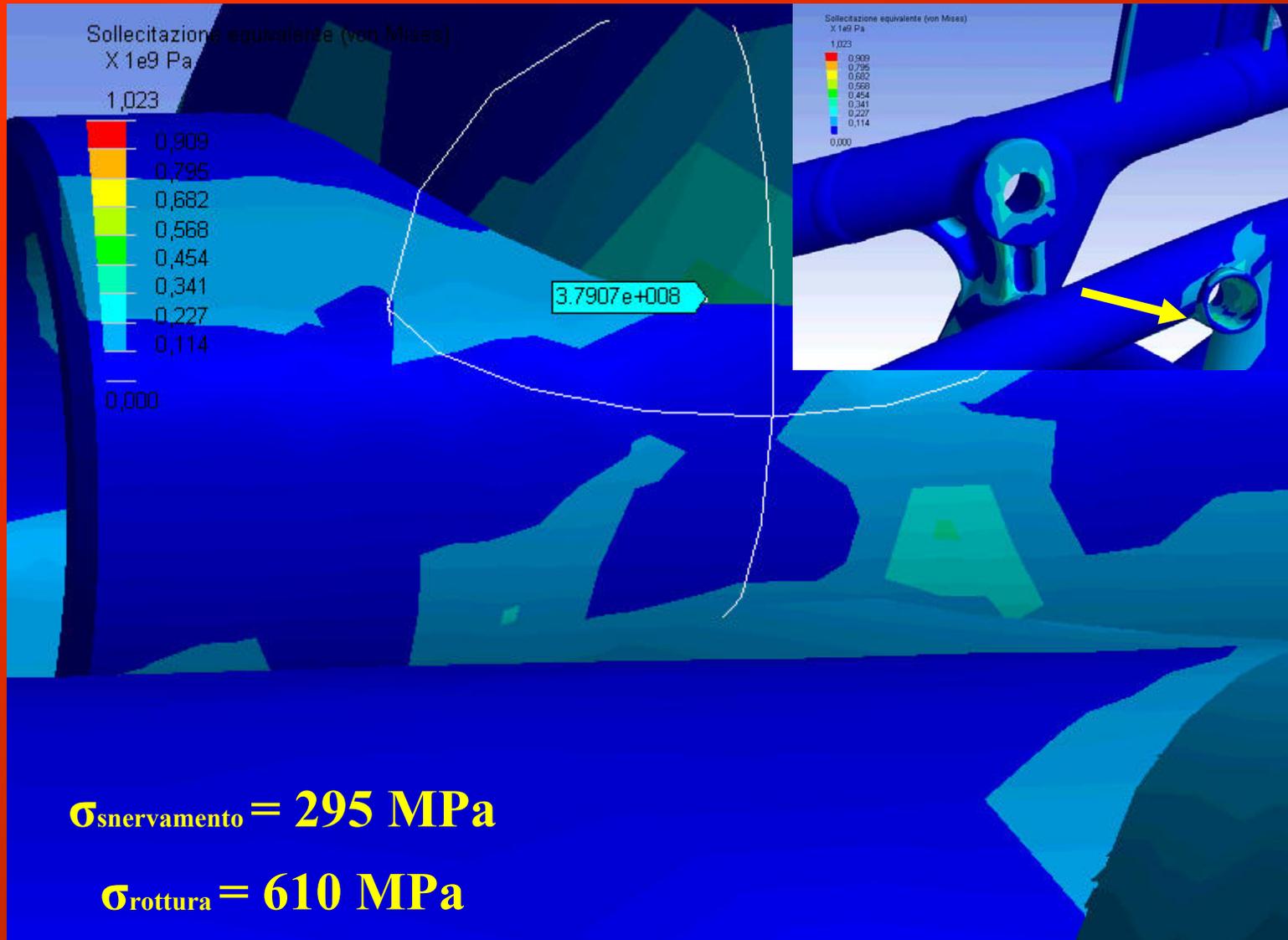
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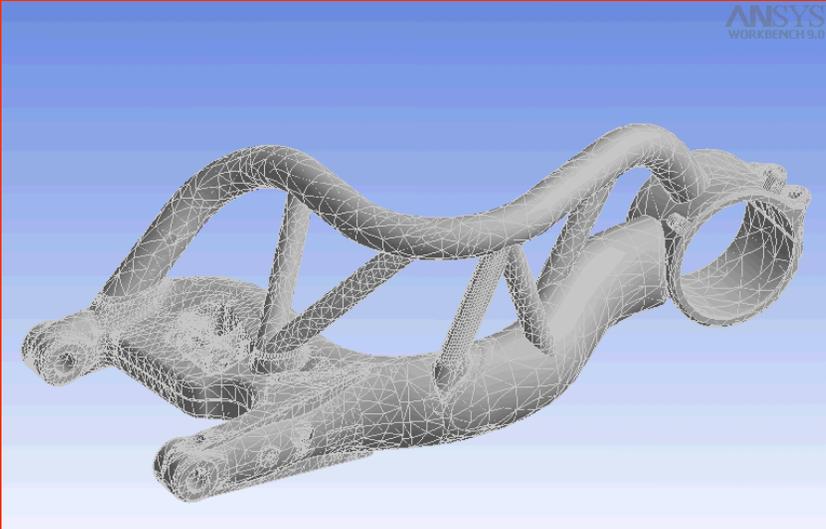


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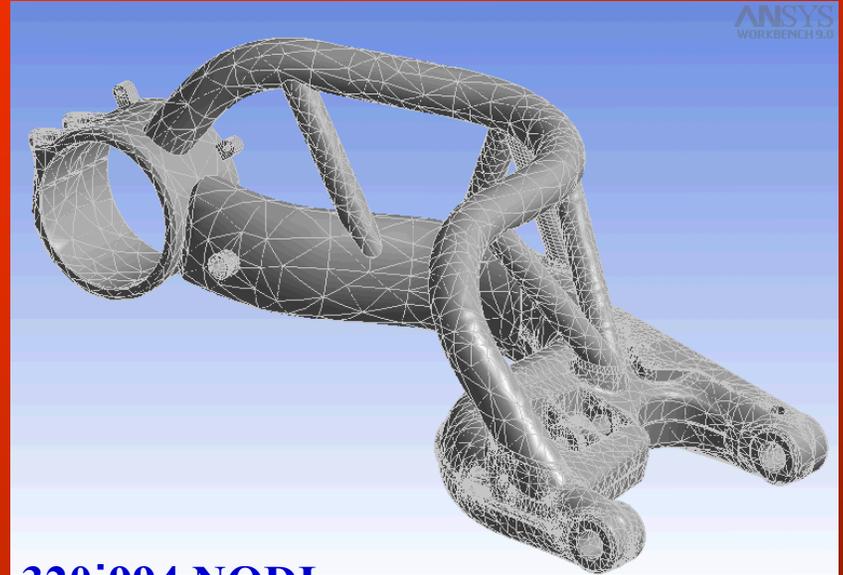


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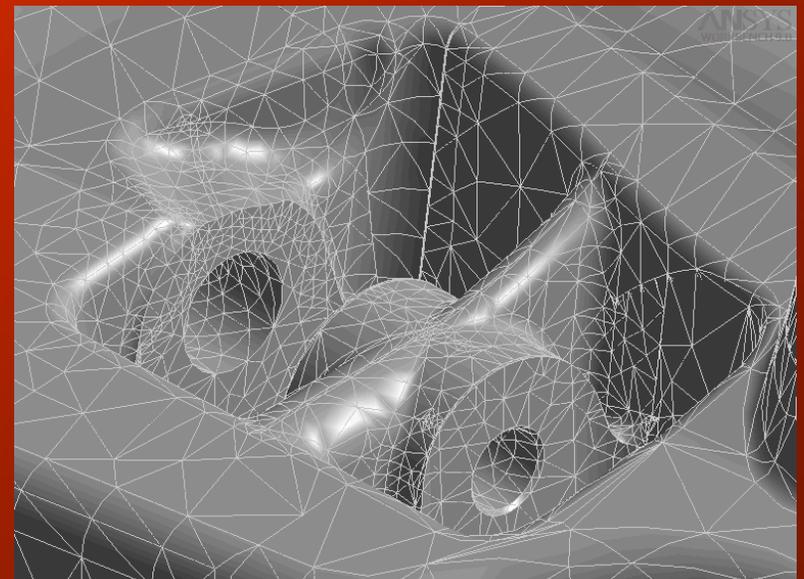
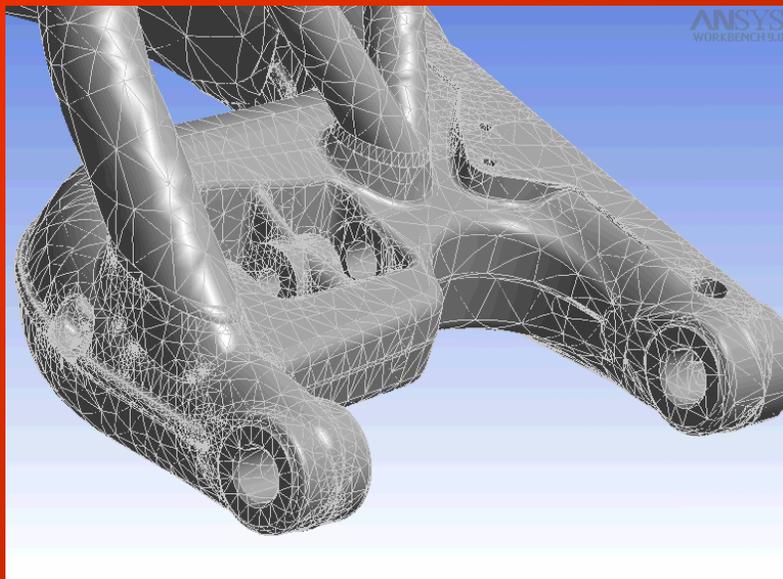


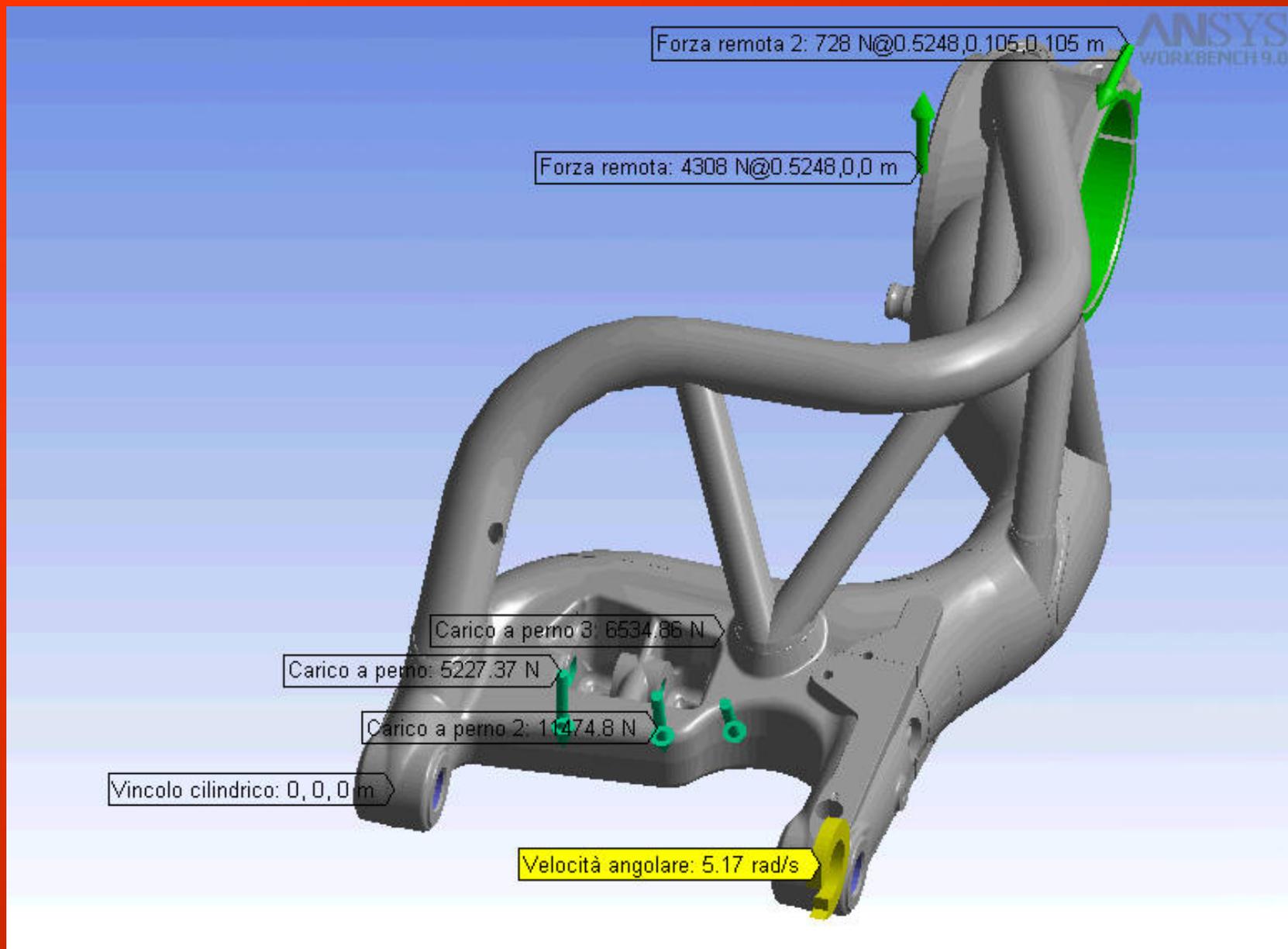


186'969 ELEMENTI

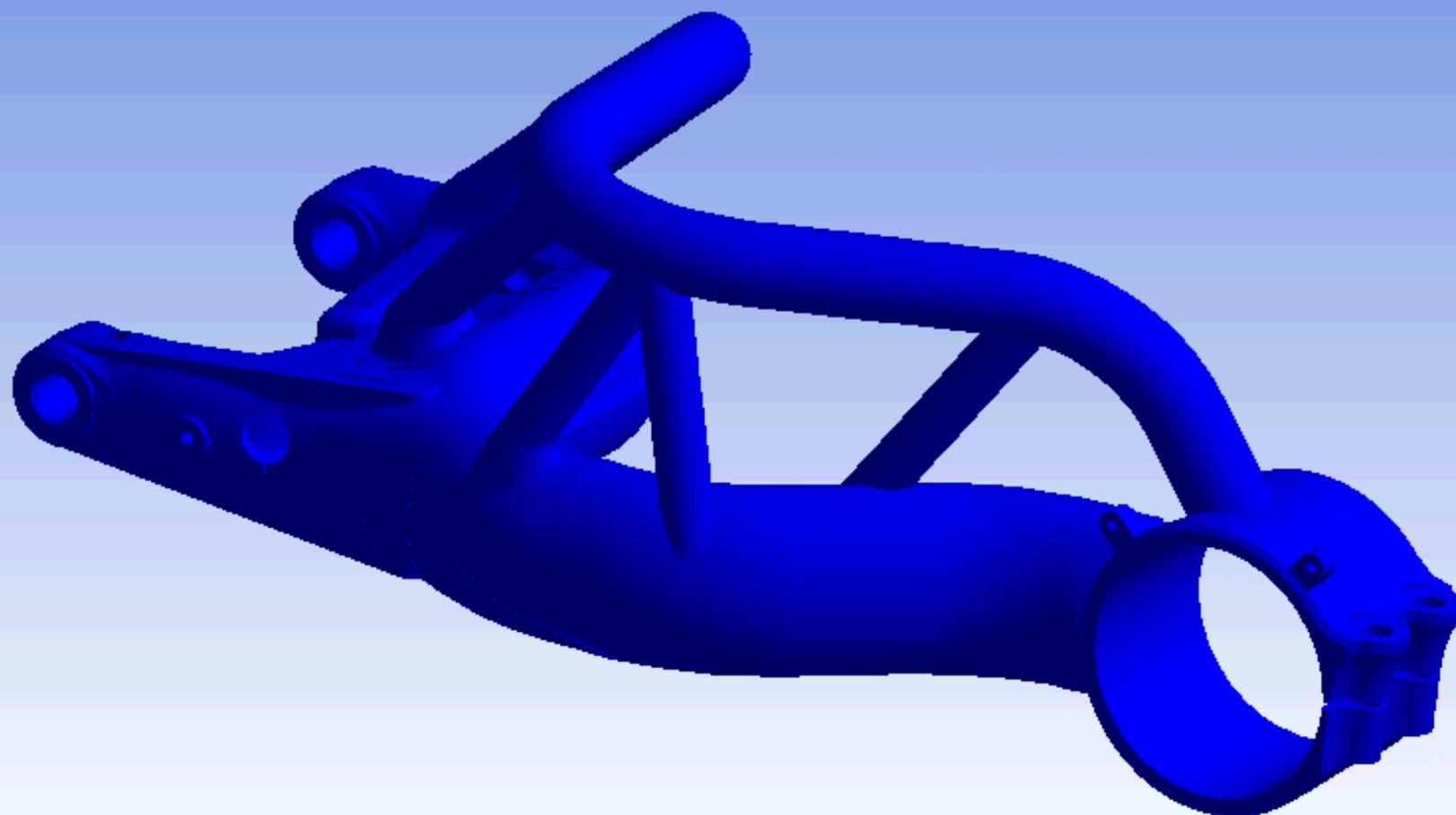


320'994 NODI

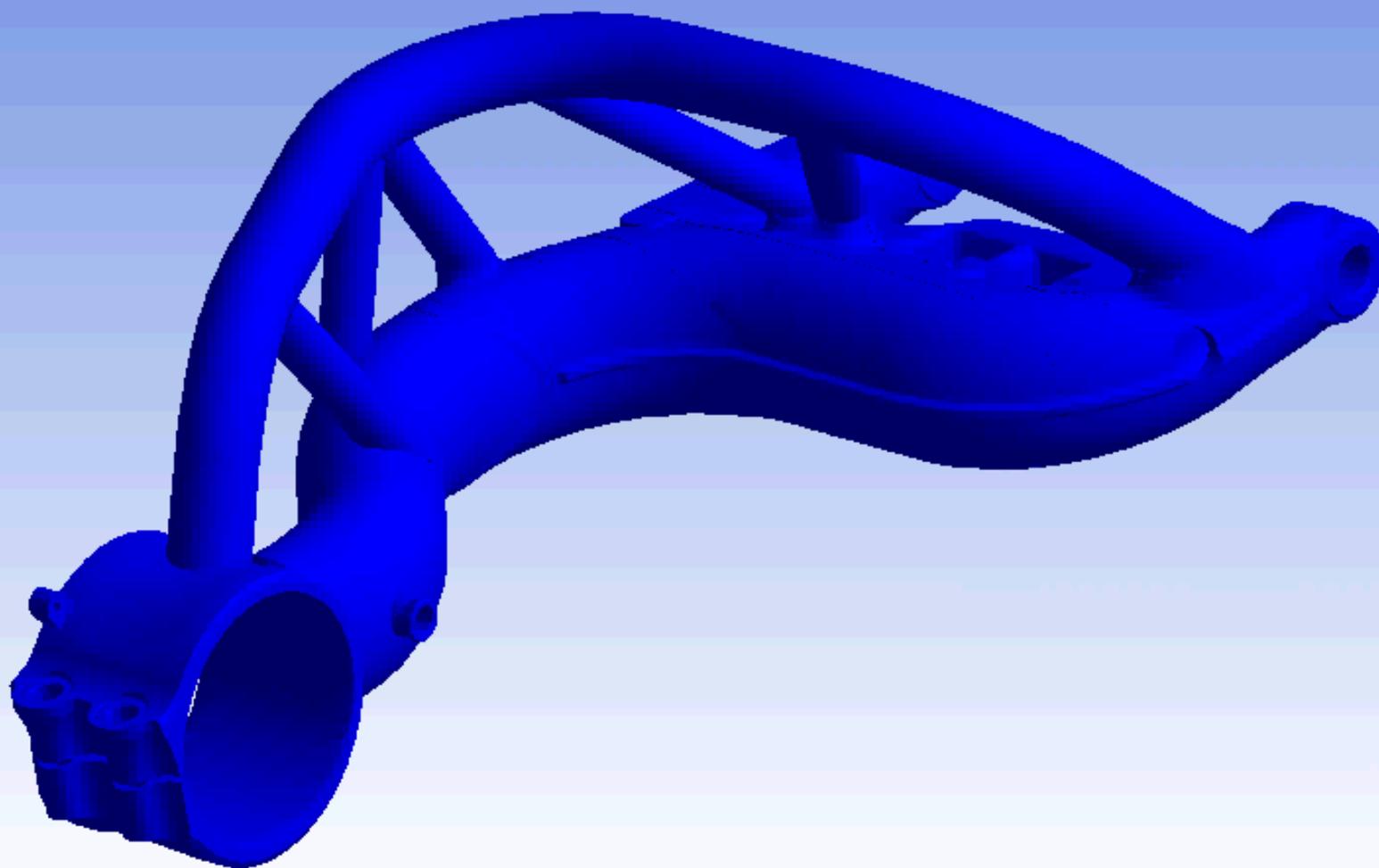




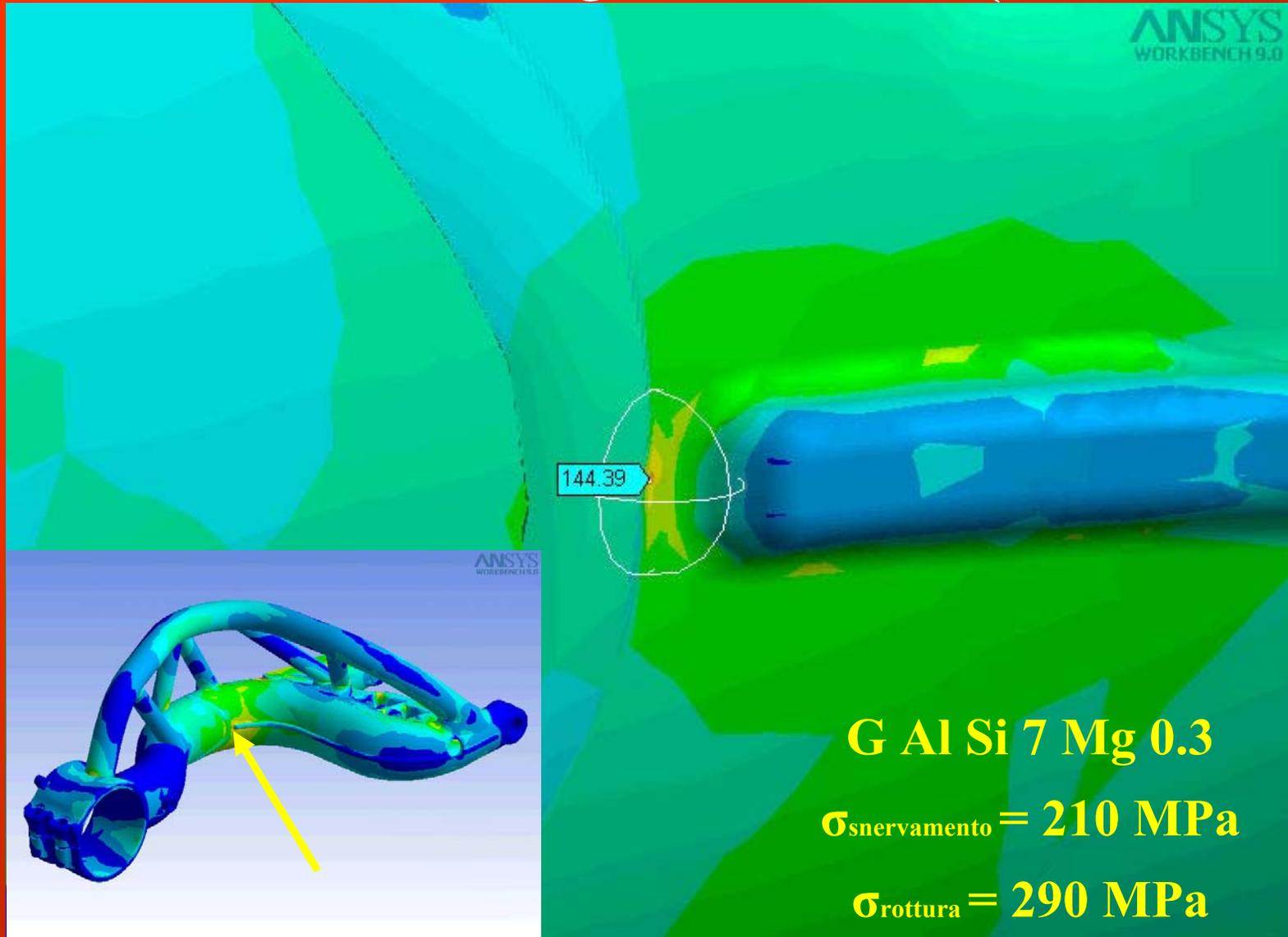
ANSYS
WORKBENCH 9.0



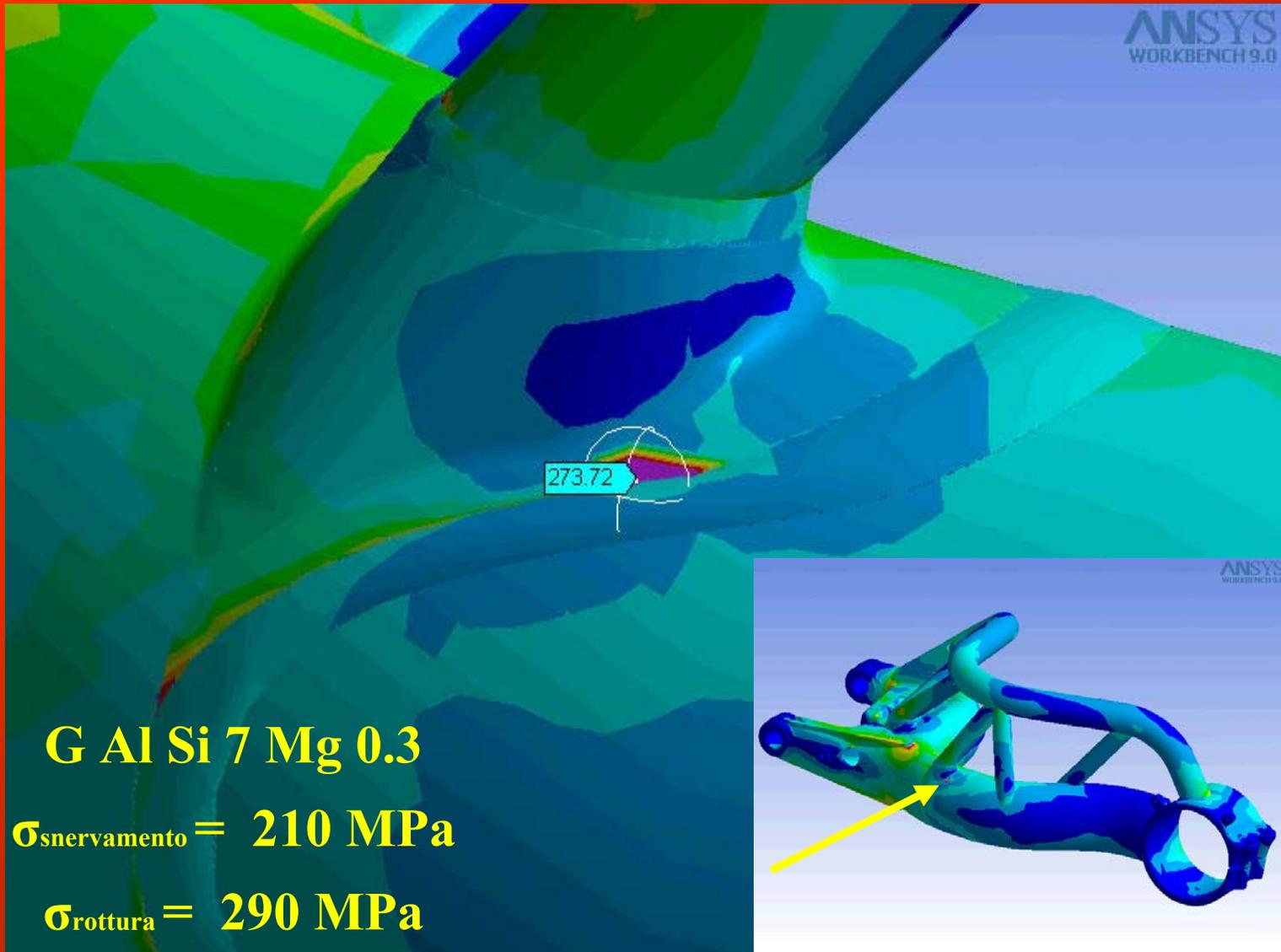
ANSYS
WORKBENCH 9.0



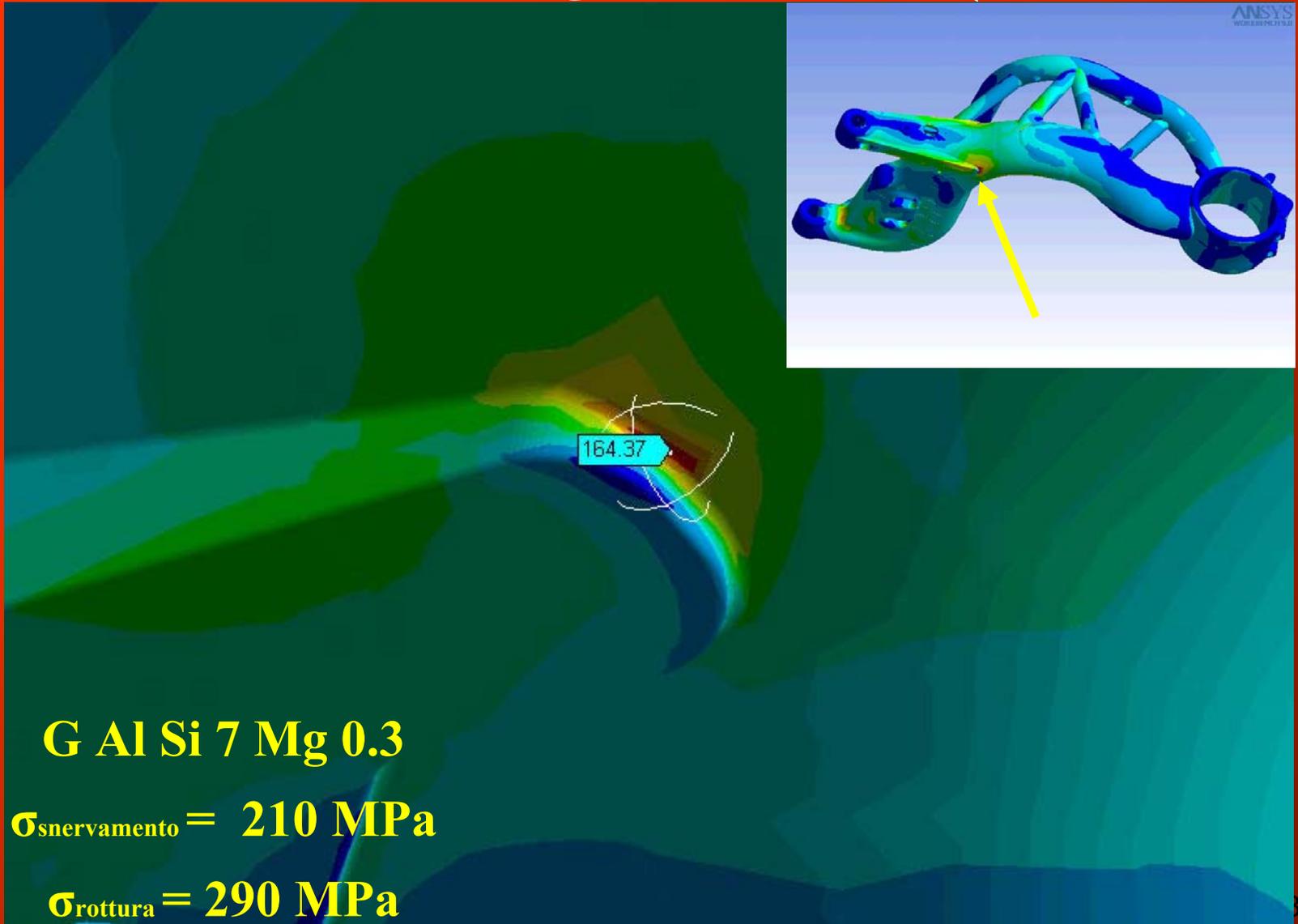
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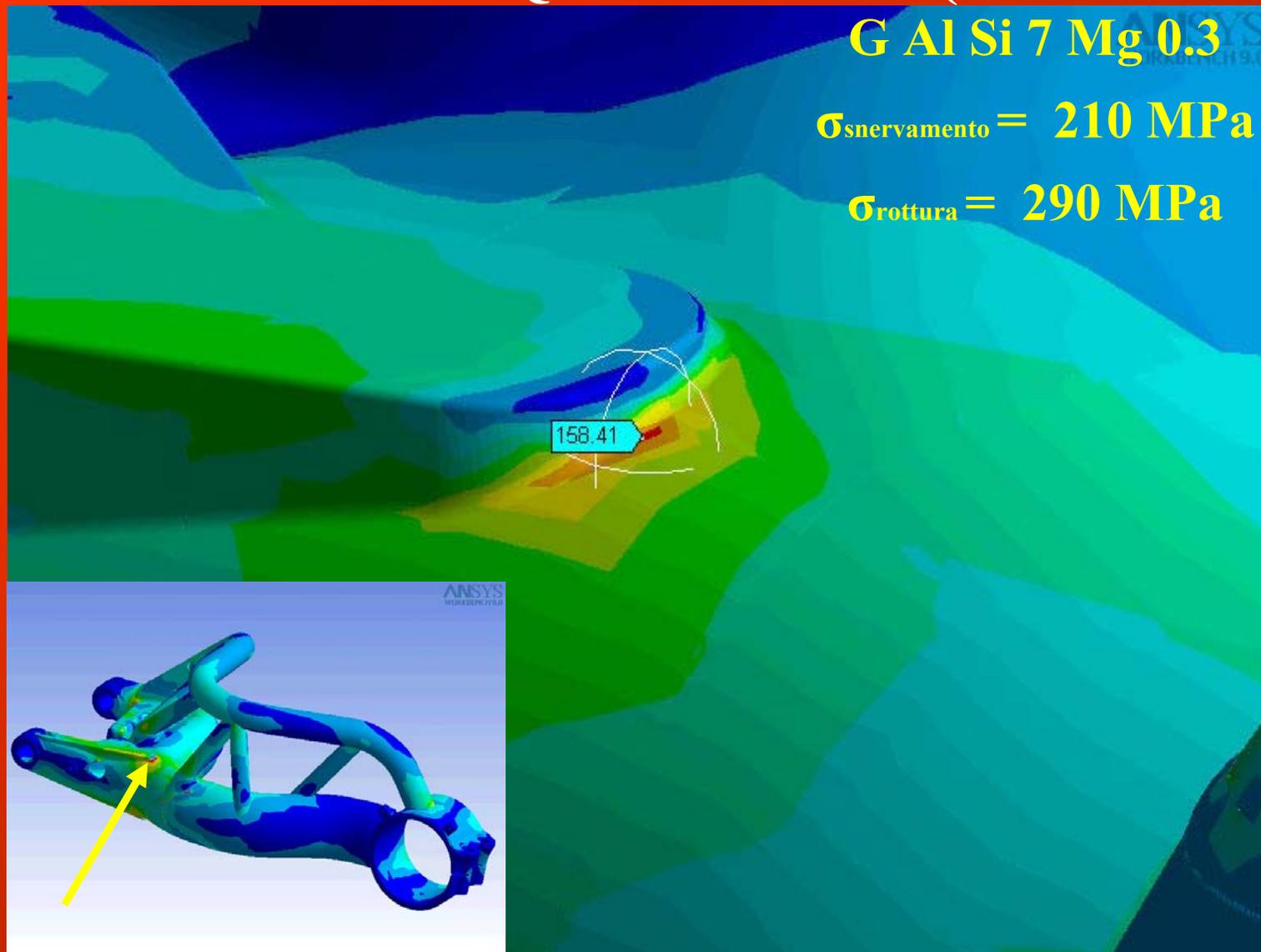
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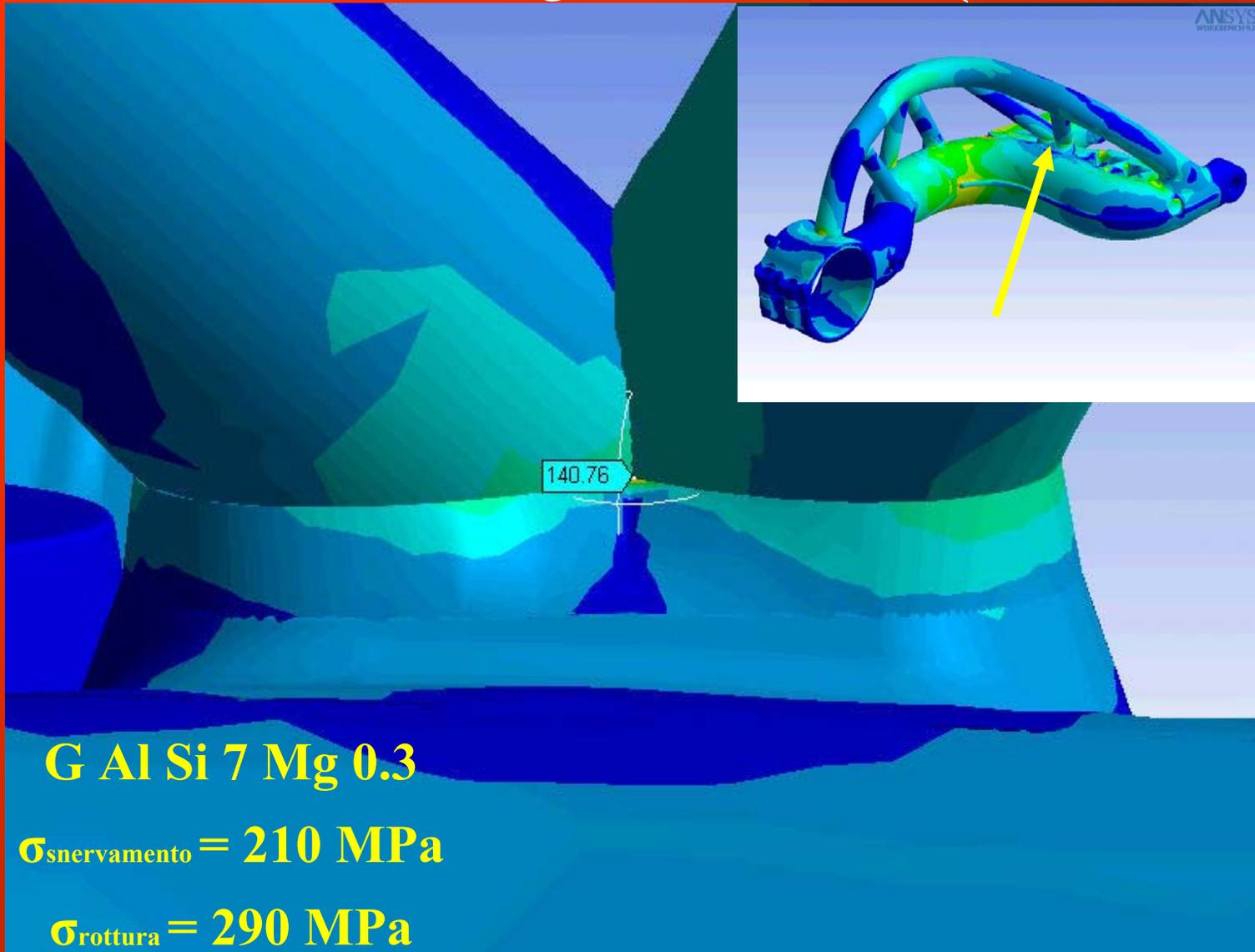
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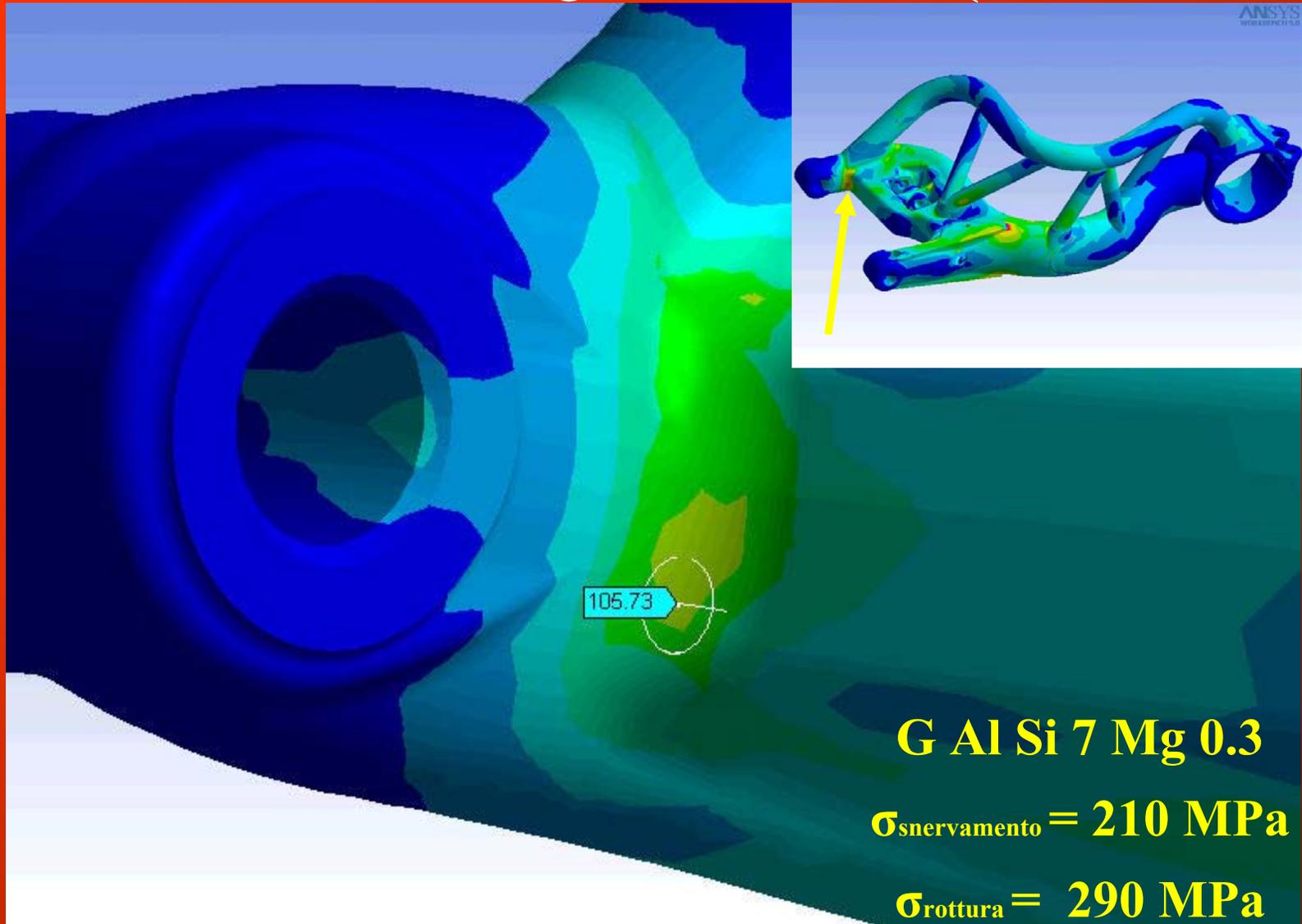
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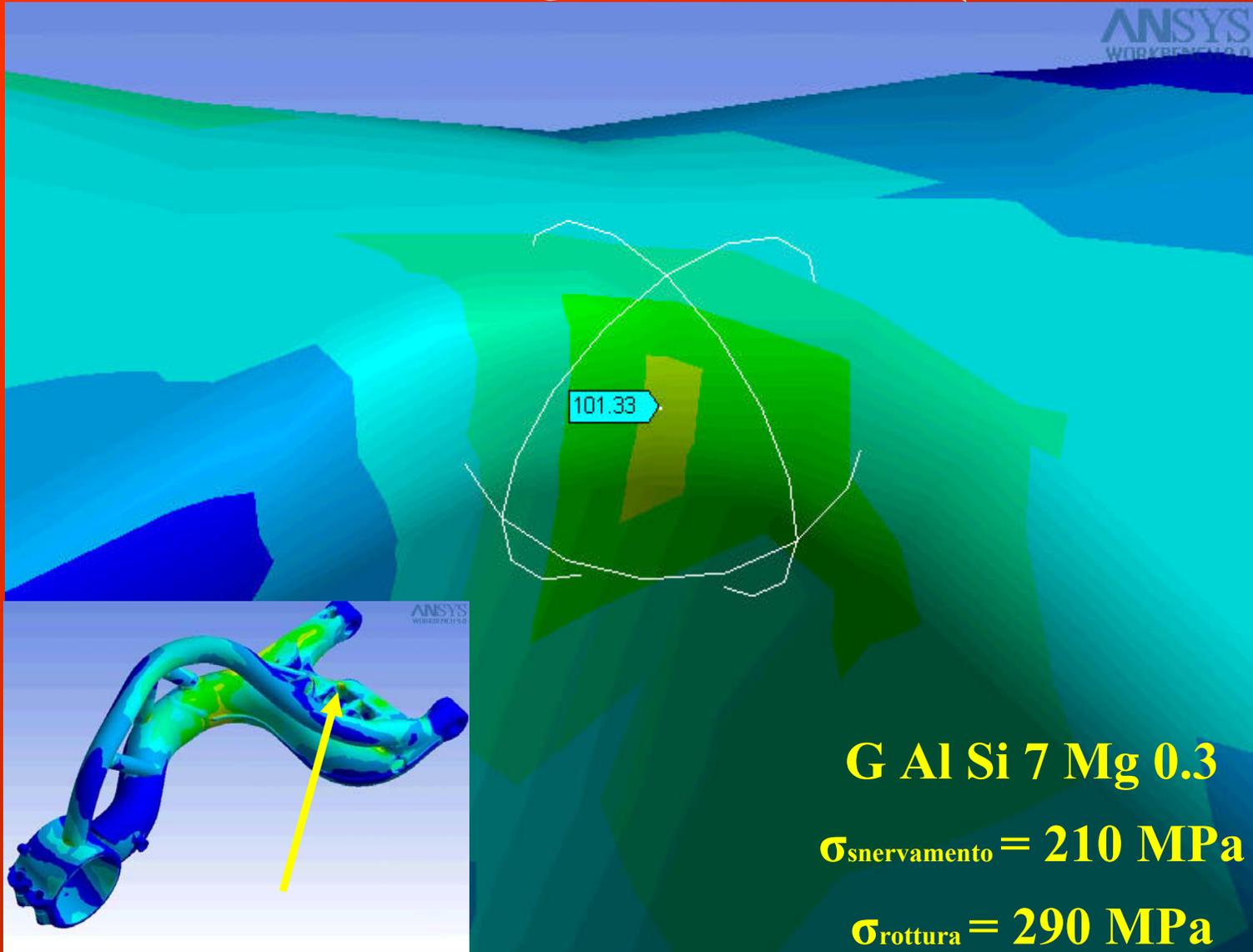
SOLLECITAZIONE EQUIVALENTE (VON MISES)



SOLLECITAZIONE EQUIVALENTE (VON MISES)



SOLLECITAZIONE EQUIVALENTE (VON MISES)

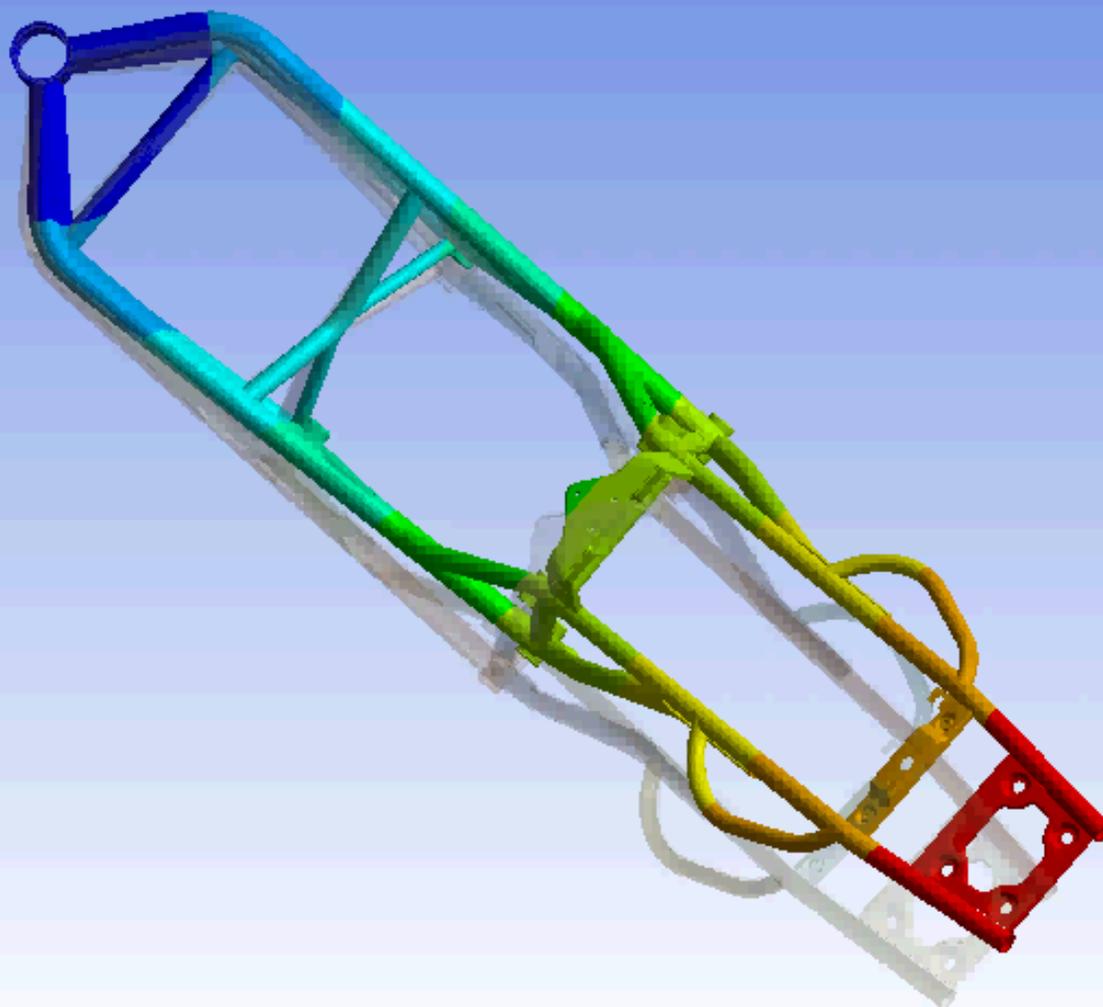
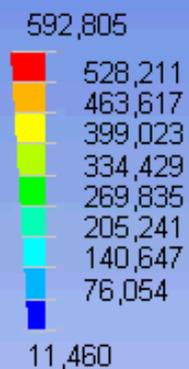




MODI DI VIBRARE DEL TELAIO

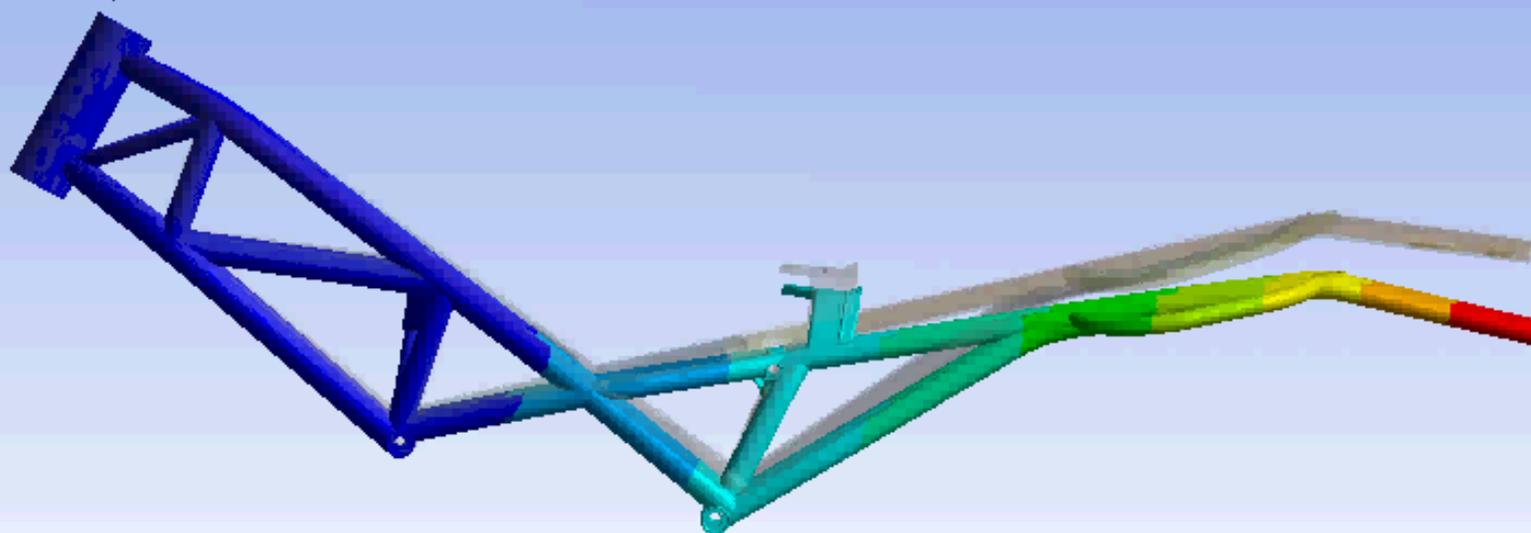
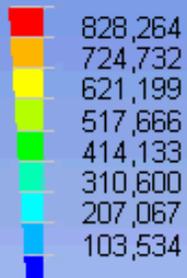


1° modo nell'intervallo (12.1879 Hz)

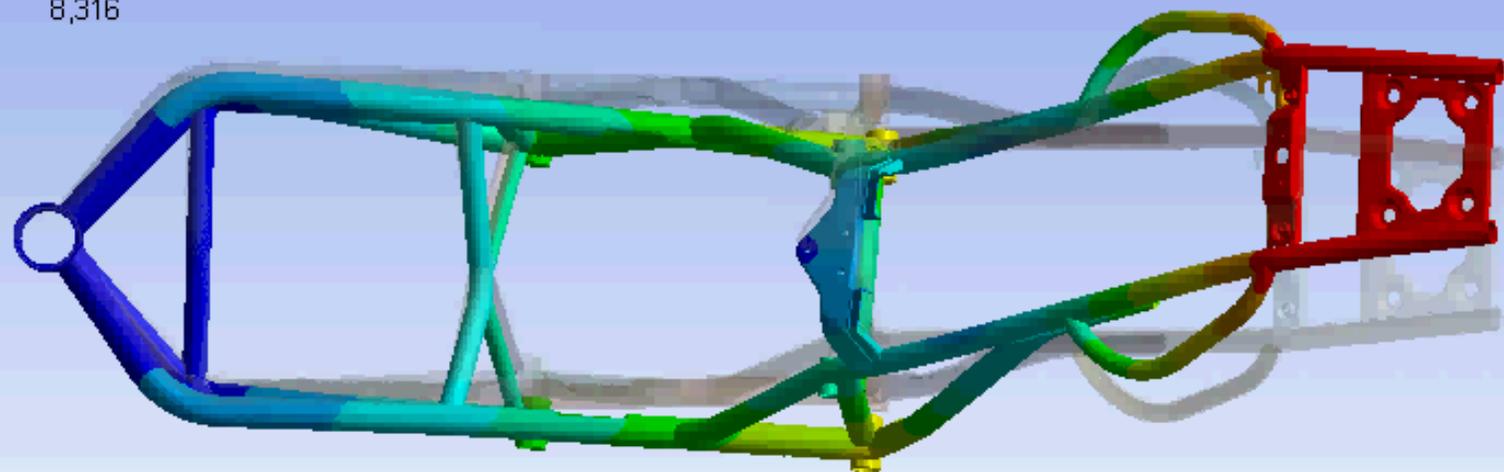
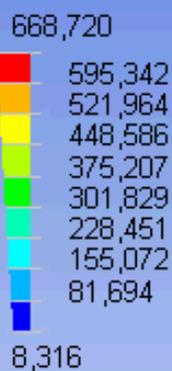


2° modo nell'intervallo (36.3408 Hz)

931,797



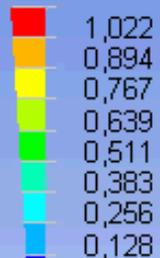
3° modo nell'intervallo (85.7443 Hz)



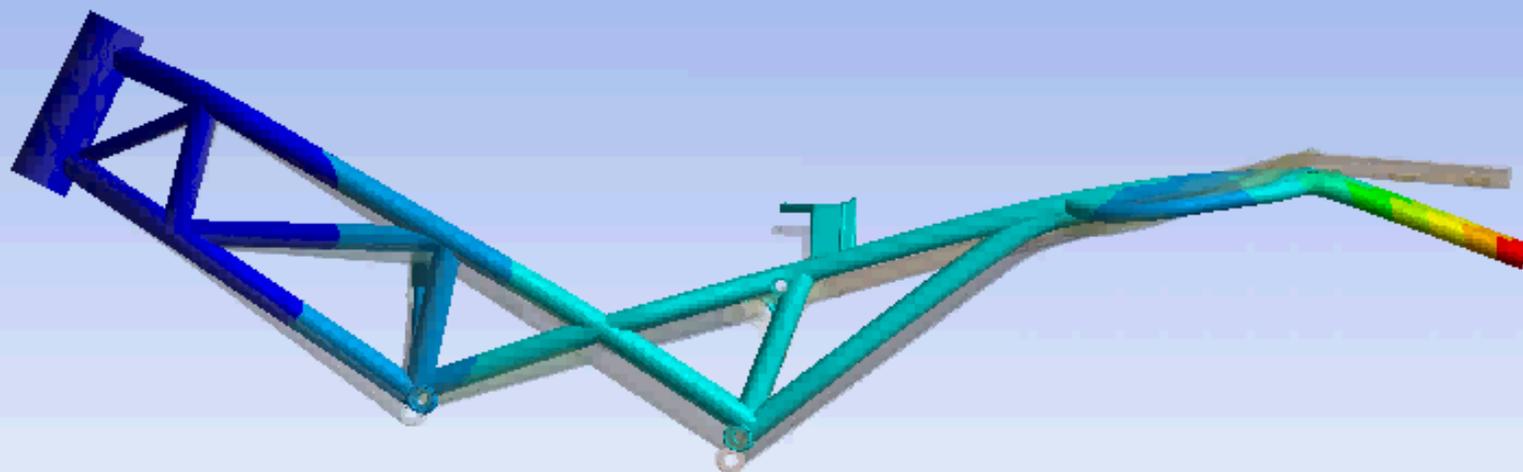
4° modo nell'intervallo (98.8894 Hz)

X 1e3

1,150



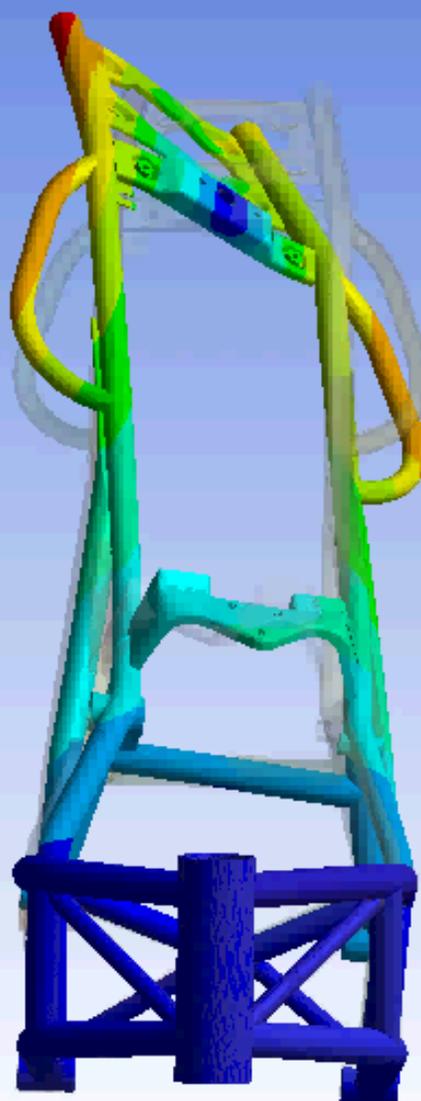
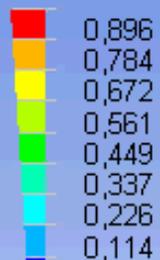
0,000



5° modo nell'intervallo (111.162 Hz)

X 1e3

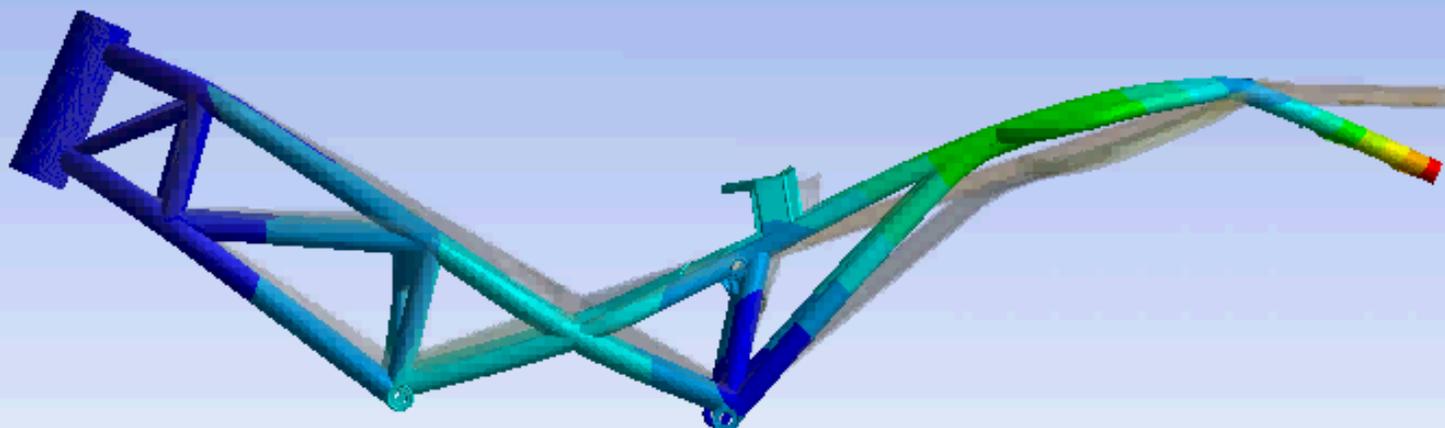
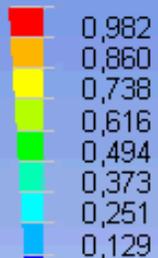
1,007



6° modo nell'intervallo (175.92 Hz)

X 1e3

1,103

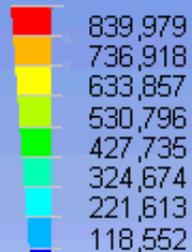




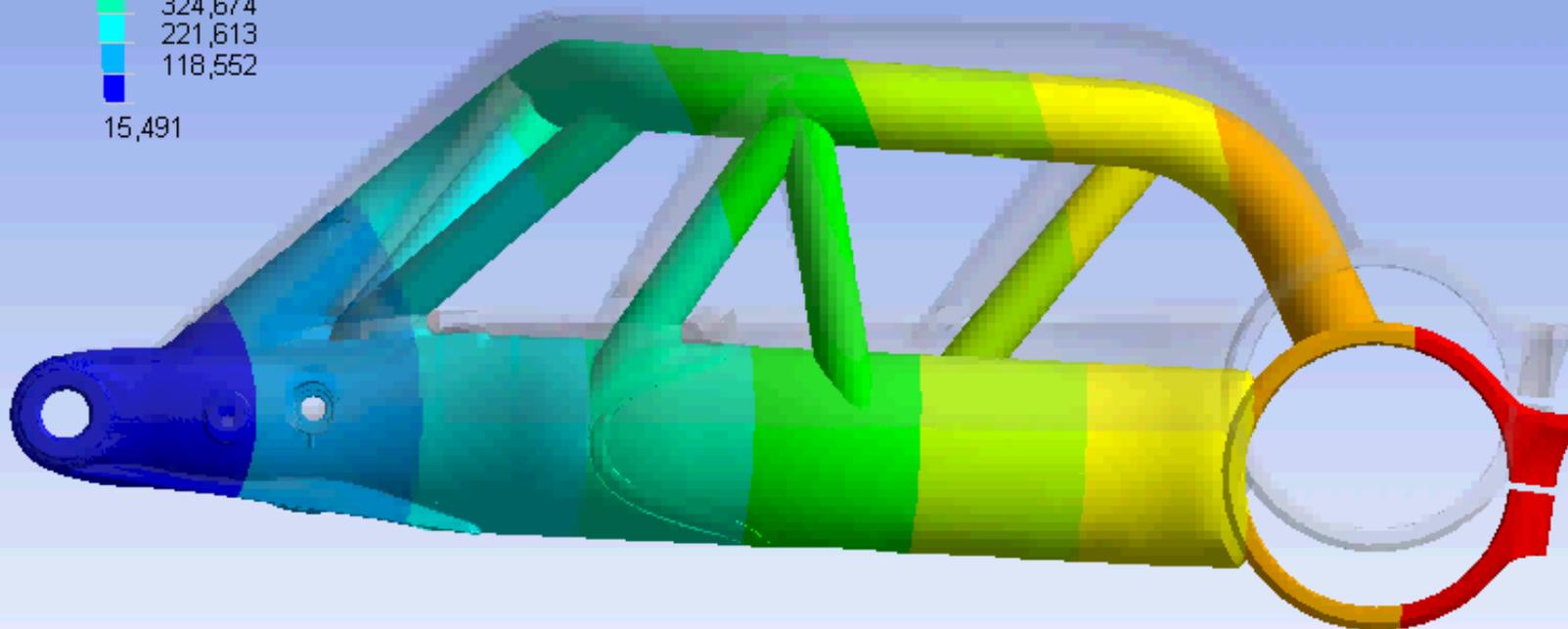
**MODI DI VIBRARE DEL
FORCELLONE**

1° modo nell'intervallo (15.4287 Hz)

943,040



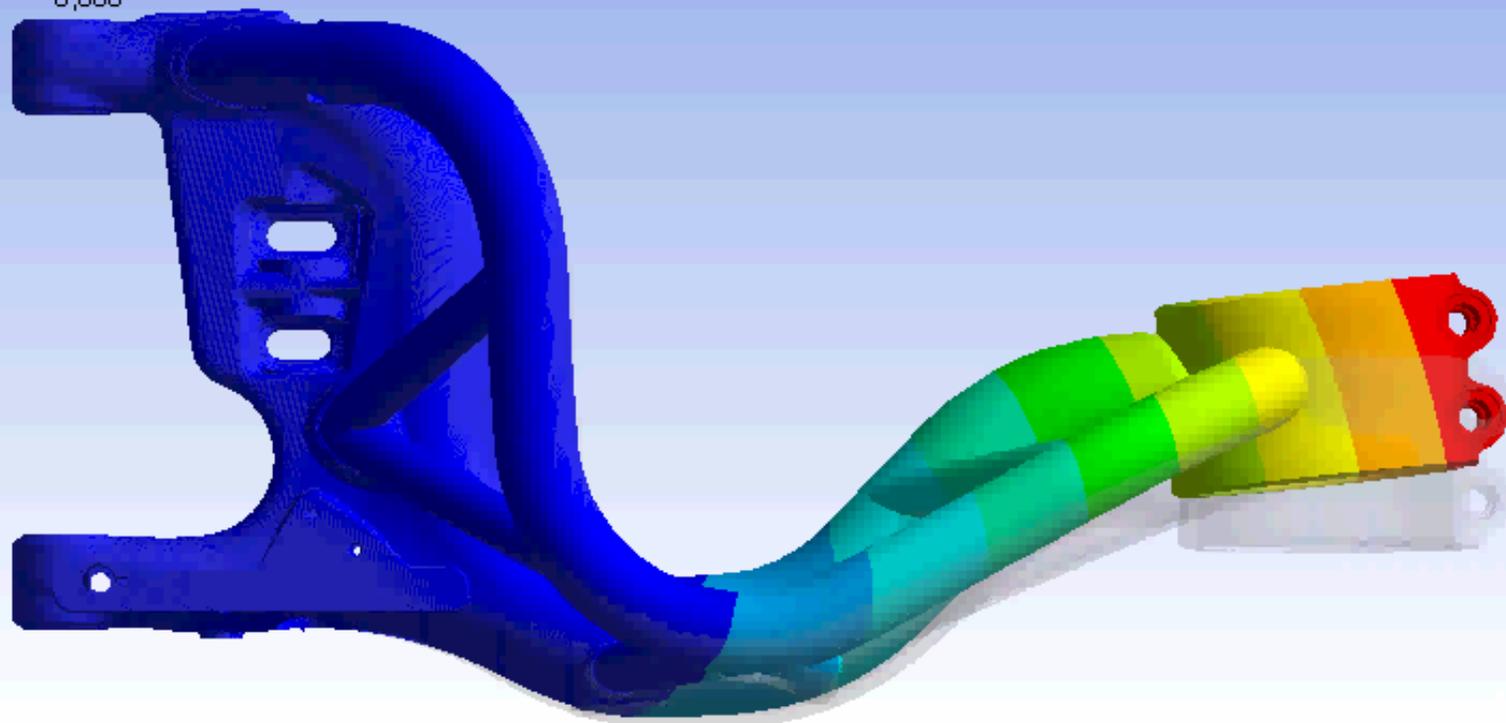
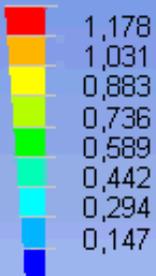
15,491



2° modo nell'intervallo (163.541 Hz)

X 1e3

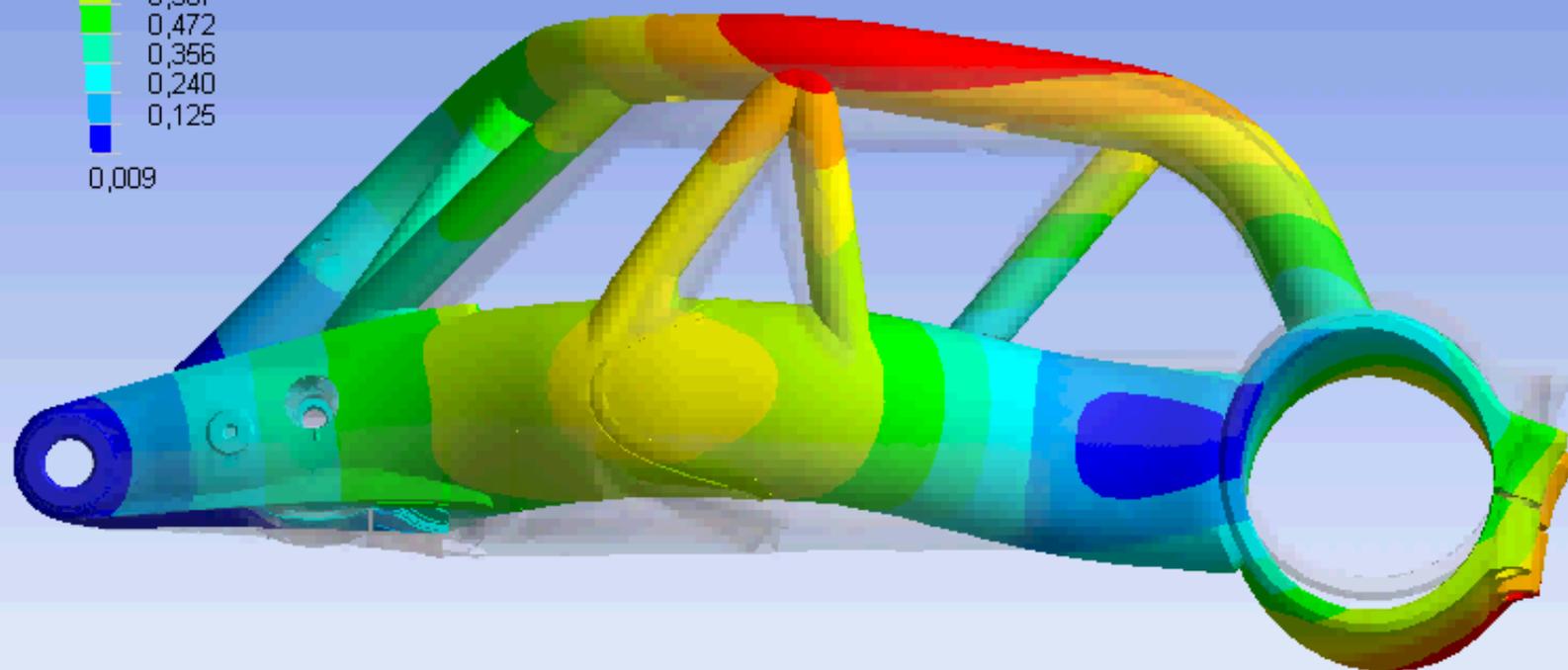
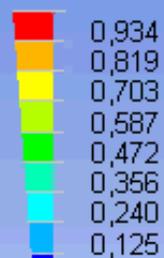
1,325



3° modo nell'intervallo (487.345 Hz)

X 1e3

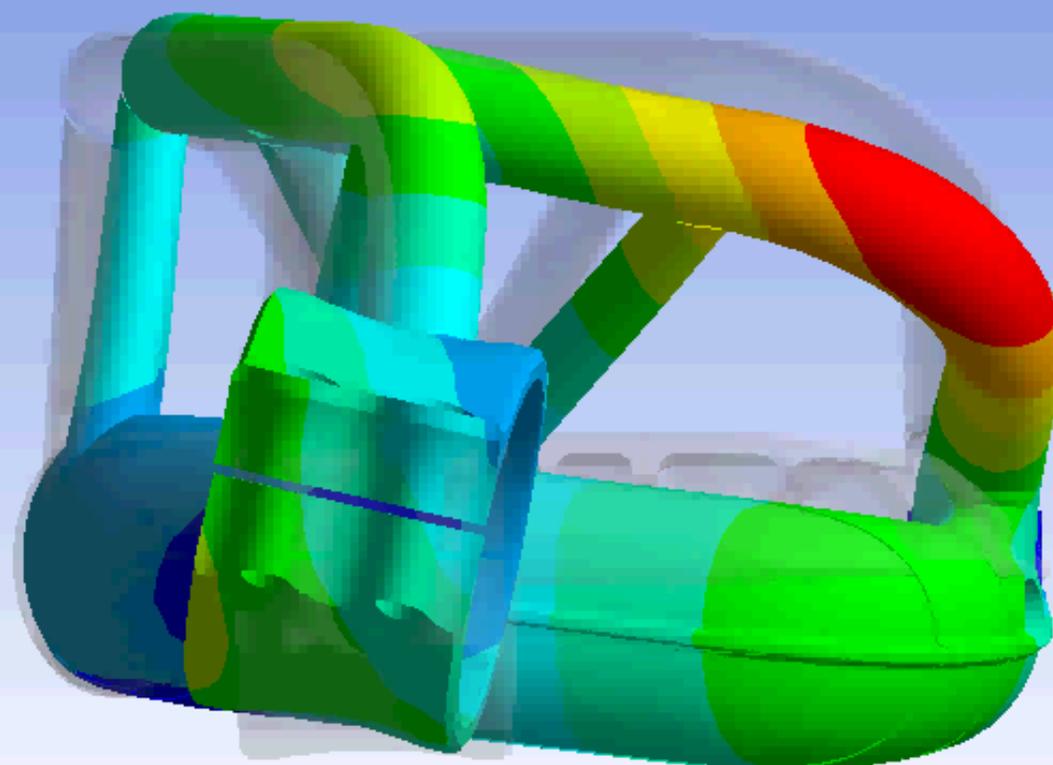
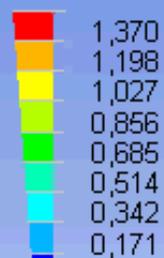
1,050



4° modo nell'intervallo (595.583 Hz)

X 1e3

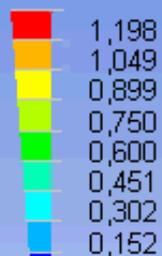
1,541



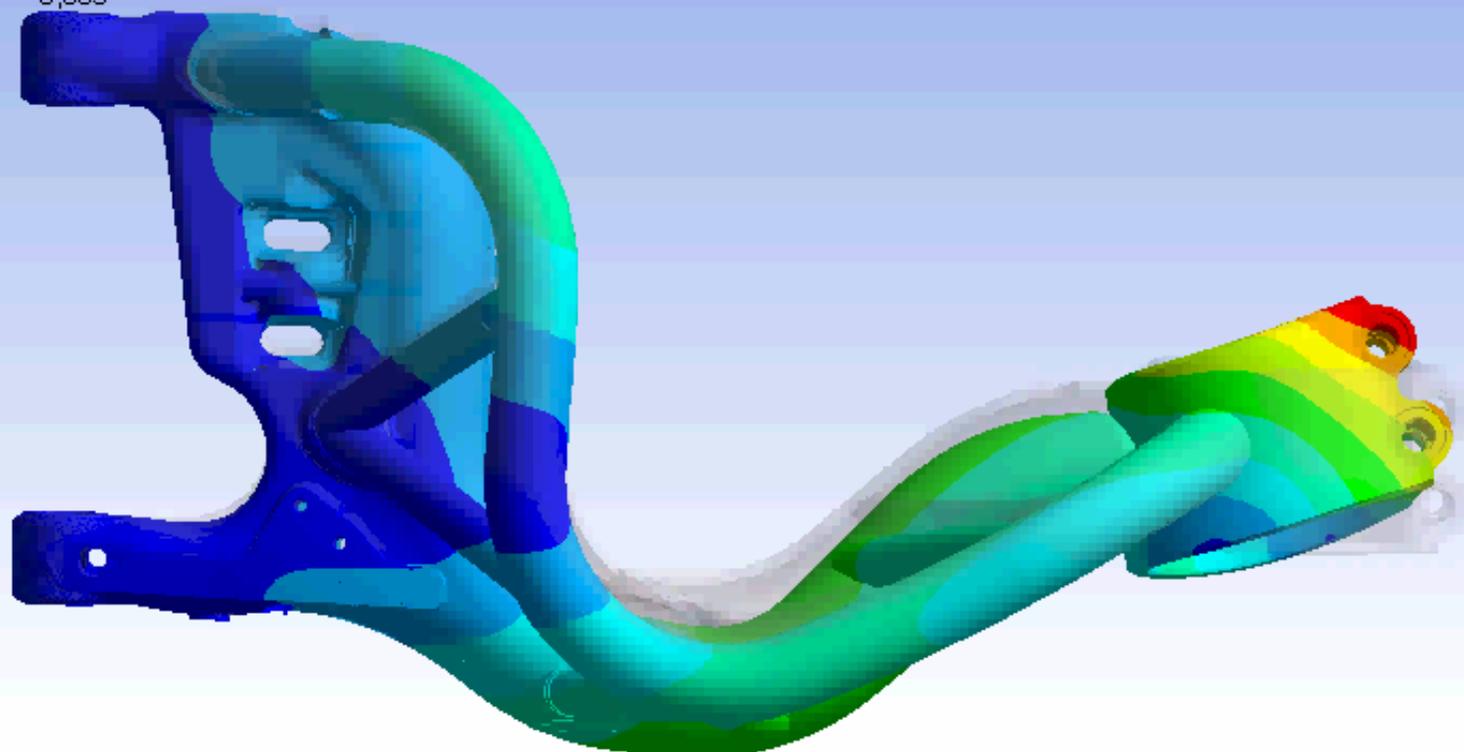
5° modo nell'intervallo (778.841 Hz)

X 1e3

1,347



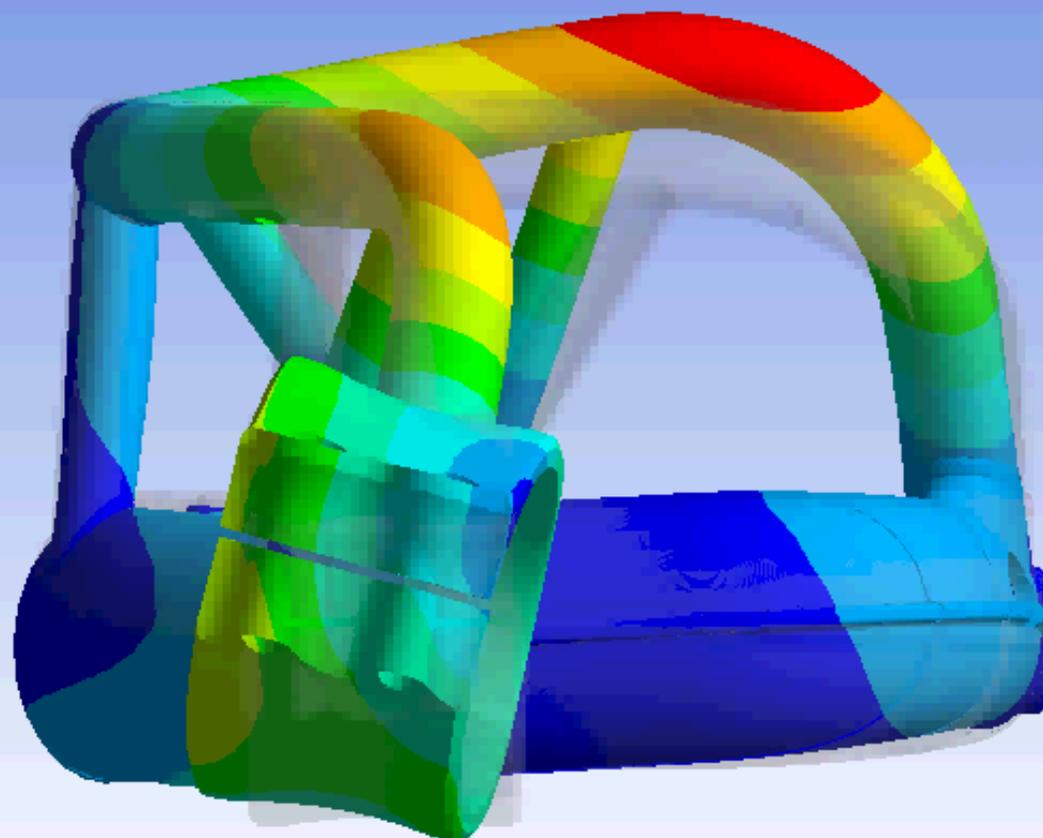
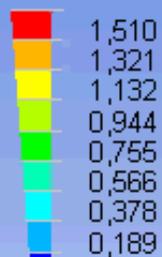
0,003



6° modo nell'intervallo (813.184 Hz)

X 1e3

1,698



ANSYS
WORKBENCH 9.0



RINGRAZIAMENTI

Prof BARTOLOZZI Giorgio

Prof PIANCASTELLI Luca

Ing CASSANI Stefano

Dir Produz Veicolo Ducati Ing FORNI Andrea

Dir Reparto Esperienze Ing GESI Andrea

**Tutto la Staff di Ingegneri e Tecnici del Reparto
Esperienze Veicolo Ducati**

Il Driver CONCORDIA Mario

